1043

AIR POLLUTION—1967

(Air Quality Act)

A11600 749968

HEARINGS

BEFORE THE

SUBC TTEE ON AIR AND WATER POLLUTION

OF THE

MITTEE ON PUBLIC WORKS

NITED STATES SENATE

NINETIETH CONGRESS

FIRST SESSION

ON

S. 780

AND RELATED MATTERS PERTAINING TO THE PREVENTION AND CONTROL OF AIR POLLUTION INCLUDING TESTIMONY ON THE CURRENT STATUS OF CONTROL TECHNOLOGY

WASHINGTON, D.C.

MAY 15, 16, 17, AND 18, 1967

PART 4

Printed for the use of the Committee on Public Works

KANSAS STATE UNIVERSITY LIBRARIES

AUTHENTICATED
U.S. GOVERNMENT
INFORMATION
GPO

AIR POLLUTION—1967
(Air Quality Act)

HEARINGS

BEFORE THE

SUBCOMMITTEE ON AIR AND WATER POLLUTION

OF THE

COMMITTEE ON PUBLIC WORKS
UNITED STATES SENATE

NINETIETH CONGRESS

FIRST SESSION

ON

S. 780

AND RELATED MATTERS PERTAINING TO THE PREVENTION AND CONTROL OF AIR POLLUTION INCLUDING TESTIMONY ON THE CURRENT STATUS OF CONTROL TECHNOLOGY

WASHINGTON, D.C.

MAY 15, 16, 17, AND 18, 1967

PART 4

Printed for the use of the Committee on Public Works

U.S. GOVERNMENT PRINTING OFFICE

77-515 O WASHINGTON : 1967

COMMITTEE ON PUBLIC WORKS

JENNINGS RANDOLPH, West Virginia, *Chairman*

STEPHEN M. YOUNG, Ohio
EDMUND S. MUSKIE, Maine
ERNEST GRUENING, Alaska
B. EVERETT JORDAN, North Carolina
DANIEL K. INOUYE, Hawaii
BIRCH BAYH, Indiana
JOSEPH M. MONTOYA, New Mexico
JOSEPH D. TYDINGS, Maryland
WILLIAM B. SPONG, Jr., Virginia

JOHN SHERMAN COOPER, Kentucky
HIRAM L. FONG, Hawaii
J. CALEB BOGGS, Delaware
GEORGE MURPHY, California
LEN B. JORDAN, Idaho
HOWARD H. BAKER, Jr., Tennessee

RICHARD B. ROYCE, *Chief Clerk and Staff Director*
BAILEY GUARD, *Assistant Chief Clerk (Minority)*
RICHARD E. GERRISH, *Minority Clerk*
JOSEPH F. VAN VLADRICKEN, LEON G. BILLINGS, J. B. HUYETT, Jr.,
M. BARRY MEYER and RICHARD D. GRUNDY, *Professional Staff Members*

SUBCOMMITTEE ON AIR AND WATER POLLUTION

EDMUND S. MUSKIE, Maine, *Chairman*

JENNINGS RANDOLPH, West Virginia
BIRCH BAYH, Indiana
JOSEPH D. TYDINGS, Maryland
DANIEL K. INOUYE, Hawaii
JOSEPH M. MONTOYA, New Mexico
WILLIAM B. SPONG, Jr., Virginia

J. CALEB BOGGS, Delaware
GEORGE MURPHY, California
JOHN SHERMAN COOPER, Kentucky
HOWARD H. BAKER, Jr., Tennessee

CONTENTS

(Complete index of witnesses and organizations appears at the end of Part 4)

HEARING DATES

	Page
May 15, 1967, Washington, D.C	2231
May 16, 1967, Washington, D.C	2407
May 17, 1967, Washington, D.C	2511
May 18, 1967, Washington, D.C	2617

CHRONOLOGICAL LIST OF WITNESSES

Washington, D.C., May 15, 1967

Dr. Edward T. Blomquist, Associate Director for Standards and Criteria Development, National Center for Air Pollution, Public Health Service, HEW, accompanied by Dr. John T. Middleton, Thomas F. Williams, and Dr. John H. Ludwig 2232

Dr. Harry W. Gehm, technical director, National Council for Stream Improvement, Pulp, Paper & Paperboard Industries 2361

Allen D. Brandt, manager, Industrial Health Engineering Division, Industrial and Public Relations Department, Bethlehem Steel Corp 2383

Washington, D.C., May 16, 1967

James R. Garvey, president and director of research, Bituminous Coal Research, Inc 2407

Dr. Walter Hibbard, Chief, Bureau of Mines, Department of the Interior, accompanied by Harry C. Allen, Jr., and William Crentz 2456

Joseph C. Stites, Jr., enterprise manager, air pollution control, Commercial Development Department, Inorganic Chemicals Division, Monsanto Co., St. Louis, Mo., accompanied by Cecil Underwood and John Miller 2467

James Jonakin, assistant manager, Kreisinger Development Laboratory, Combustion Engineering, Inc., Windsor, Conn 2473

H. H. Meredith, Jr., coordinator of air and water conservation, Humble Oil & Refining Co., representing the American Petroleum Institute, accompanied by C. W. Lubbock, member of the task force, American Petroleum Institute, Houston, Tex 2487

Sherman K. Reed, director, central research department, FMC Corp., accompanied by Norris J. Brunsvold, FMC Corp., Princeton, N.J 2504

Washington, D.C., May 17, 1967

Dr. John T. Middleton, Director, National Center for Air Pollution Control, Public Health Service, accompanied by Dr. Edward T. Blomquist, Associate Director for Standards and Criteria Development; Tom Williams and Dr. John H. Ludwig 2513

Charles F. Avila, president-elect, Edison Electric Institute; chairman, Edison Electric Institute Division, and executive committee chairman of the board of Boston Edison Co., accompanied by T. T. Frankenberg, consulting mechanical engineer for the American Electric Power Co., and Maynard Smith, leader of the Meteorological Group, Brookhaven National Laboratory 2544

Jerome Wilkenfeld, Air Quality Committee, Manufacturing Chemists Association, accompanied by Emmet F. Spencer, Jr., pollution control engineer 2594

Leonard S. Wegman, president, Leonard S. Wegman Co., representing Consulting Engineers Council of America 2611

WASHINGTON, D.C., MAY 18, 1967

Bruce E. Kester, director of research, Missouri Portland Cement Co., representing Cement Advisory Committee, American Mining Congress, accompanied by Jack Gilliland, director of quality control, Ideal Cement Co. — Page 2617
Earl L. Wilson, president, Industrial Gas Cleaning Department, Kopper Co., Inc., accompanied by Charles A. Gallaer and Herbert R. Herington — 2629
Gerard C. Gambs, assistant to vice president, chemicals, Consolidation Coal Co., accompanied by Ernest W. Anderson, advertising manager — 2649
Louis C. McCabe, president, Resources Research, Inc., subsidiary of Hazleton Laboratories, Inc., accompanied by John S. Lagarias and Harold MacFarland — 2659
Dr. Eric J. Cassell, associate professor of community medicine, Mount Sinai School of Medicine, New York, N.Y — 2668

ADDITIONAL INFORMATION SUBMITTED FOR THE RECORD

Analysis of Stone & Clarke paper presented to the subcommittee on May 10, 1967 — 2283
AQ & ED Branch, NASN Section, commuter exposure to carbon monoxide — 2263
Coal gasifier/gas turbine method of electric power generation — 2451
Commonwealth of Pennsylvania, Department of Health, Air Pollution Commission, ambient air quality criteria — 2396
Control of dust emission—combustion for indirect heat exchangers — 2419
Evidence concerning the effects of sulfur dioxide — 2531
High stacks for the diffusion of sulfur dioxide and other gases emitted by electric powerplants — 2557
Letter of April 21, 1967, from Senator Muskie to Dr. John Middleton — 2346
Letter of March 31, 1967, from Senator Muskie to Dr. John Middleton — 2333
Marketing fly ash—U.S. and European programs — 2653
Mechanical collectors — 2640
Mixing depths, wind speeds, and air pollution potential for selected locations in the United States — 2287
Pioneering experience with high stacks on the OVEC and American Electric Power Systems — 2550
Reduction of ambient air concentrations of pollutants by dispersion from high stacks — 2567
Senator Randolph discusses the need for parity in Government research financing of nuclear power investigation on the one hand and coal on the other — 2454
SO_2 control project list — 2328
Status of current technology in the control of emissions to the atmosphere — 2274
Summary of air pollution control program grants by States — 2347
Summary of air sampling stations—1967 — 2240
Summary of continuous monitoring—1966 — 2246
Summary of funds allocated for SO_2 control projects, fiscal year 1967 — 2327
Summary of I.G.C.I. research and development information survey — 2639
Use of particulate collection by industry — 2637

STATEMENTS

Avila, Charles F., president-elect, Edison Electric Institute, chairman, Edison Electric Institute Division, and executive committee chairman of the board of Boston Edison Co., accompanied by T. T. Frankenberg, consulting mechanical engineer for the American Electric Power Co.; and Maynard E. Smith, leader of the Meteorological Group, Brookhaven National Laboratory — 2544
Blomquist, Dr. Edward T., Associate Director for Standards and Criteria Development Programs, National Center for Air Pollution Control, Public Health Service, U.S. Department of Health, Education, and Welfare, accompanied by Dr. John T. Middleton, Director, National Center for Air Pollution Control; Thomas F. Williams, Chief, Office of Legislative and Public Affairs; and Dr. John H. Ludwig, Associate Director for Control Technology Research and Development, National Center for Air Pollution Control — 2232

Page

Brandt, Allen D., manager, Industrial Health Engineering Division, Industrial and Public Relations Department, Bethlehem Steel Corp ---- 2383
Cassell, Dr. Eric J., associate professor of community medicine and associate professor of medicine, Mount Sinai School of Medicine, New York, N.Y ---- 2668
Fixman, Ben, president, Diversified Metals Corp ---- 2542
Frankenberg, T. T., consulting mechanical engineer, American Electric Power Co ---- 2548
Gambs, Gerard C., assistant to vice president, chemicals, Consolidation Coal Co.; accompanied by Ernest W. Anderson, advertising manager -- 2649
Garvey, James R., president and director of research, Bituminous Coal Research, Inc., Monroeville, Pa ---- 2407
Gehm, Dr. Harry W., technical director, National Council for Stream Improvement of the Pulp, Paper & Paperboard Industries, accompanied by Ernest J. Bolduc, Jr., executive secretary ---- 2361
Hibbard, Dr. Walter R., Jr., Director, Bureau of Mines, Department of the Interior, accompanied by Harry C. Allen, Jr ---- 2456
Intemann, H. K., Union Carbide Corp.: Letter dated May 17, 1967 ---- 2606
Jonakin, James, assistant manager, Kreisinger Development Laboratory, Combustion Engineering, Inc., Windsor, Conn ---- 2473
Kester, Bruce E., director of research, Missouri Portland Cement Co., representing Cement Advisory Committee, American Mining Congress, accompanied by Jack Gilliland, director of quality control, Ideal Cement Co ---- 2617
Long, Hon. Edward V. a U.S. Senator from the State of Missouri ---- 2231
Ludwig, Dr. John H., Associate Director for Control Technology Development Program, National Center for Air Pollution Control, Public Health Service ---- 2265
McCabe, Louis C., president, Resources Research, Inc., subsidiary of Hazleton Laboratories, Inc., and chairman of the board, Hazleton Laboratories, Inc., accompanied by John S. Lagarias, executive vice-president, Resources Research, Inc., and Harold N. MacFarland, vice president, Resources Research, Inc., and director, Inhalation Division, Hazleton Laboratories, Inc ---- 2659
Meredith, H. H., Jr., coordinator of air and water conservation, Humble Oil & Refining Co., representing the American Petroleum Institute, accompanied by C. W. Lubbock, member of the task force, American Petroleum Institute, Houston, Tex ---- 2487
Middleton, John T., Director, National Center for Air Pollution Control, Public Health Service; accompanied by Dr. Edward T. Blomquist, Associate Director for Standards and Criteria Development Programs; Thomas F. Williams, Chief, Office of Legislative and Public Affairs, and Dr. John H. Ludwig ,Associate Director, Control Technology Research and Development ---- 2513
Mintz, Robert, chairman, Air Pollution Committee, the Harvard Conservation Club, Harvard University, Cambridge, Mass.: Letter dated May 12, 1967 ----
Pollock, W. A., Wisconsin Electric Power Co.: Letter dated April 18, 1967 - 2681
Reed, Sherman K., director, Central Research Department, FMC Corp., 2592
accompanied by Norris J. Brunsvold, FMC Corp., Princeton, N.J ---- 2504
Ribicoff, Hon. Abraham A., a U.S. Senator from the State of Connecticut - 2512
Seaborg, Glenn T., Chairman, U.S. Atomic Energy Commission ---- 2682
Smith, Maynard E., leader of the Meteorological Group, Brookhaven National Laboratory ---- 2566
Stites, Dr. Joseph C., Jr., enterprise manager, air pollution control, commercial development department of the Inorganic Chemicals Division, Monsanto Co., St. Louis, Mo., accompanied by Cecil Underwood, Washington, D.C., regional vice president, Monsanto Co.; Ralph F. Bovier, Johnstown, Pa., vice president-technical, Pennsylvania Electric Co.; and John G. Miller, Reading, Pa., chief engineer, Metropolitan Edison Co -- 2467
Wegman, Leonard S., partner, Leonard S. Wegman Co., representing Consulting Engineers Council of America ---- 2611

Page

Wilkenfeld, Jerome, Manufacturing Chemists Association, accompanied by Emmet F. Spencer, Jr. 2594

Wilson, Earl L., president, Industrial Gas Cleaning Institute, and manager, Industrial Gas Cleaning Department, Koppers Co., Inc.; accompanied by Charles A. Gallaer, chief engineer, Buell Engineering Co., and member, Engineering Standards Committee, Industrial Gas Cleaning Institute; and Herbert R. Herington, executive secretary, Industrial Gas Cleaning Institute 2629

ORGANIZATIONS

American Electric Power Co. 2544, 2548
American Petroleum Institute 2487
Bethlehem Steel Corp. 2383
Bituminous Coal Research, Inc., Monroeville, Pa. 2407
Brookhaven National Laboratory 2544, 2566
Cement Advisory Committee, American Mining Congress 2617
Combustion Engineering, Inc., Windsor, Conn. 2473
Consolidation Coal Co. 2649
Consulting Engineers Council of America 2606
Department of Health, Education, and Welfare 2232, 2265, 2513
Department of the Interior 2456
Diversified Metals Corp. 2542
Edison Electric Institute 2544
FMC Corp., Princeton, N.J. 2504
Harvard University, Cambridge, Mass. 2681
Humble Oil & Refining Co., Houston, Tex. 2487
Industrial Gas Cleaning Institute 2629
Manufacturing Chemists Association 2594
Metropolitan Edison Co. 2467
Monsanto Co., St. Louis, Mo. 2467
Mount Sinai School of Medicine, New York, N.Y. 2668
National Council for Stream Improvement, Pulp, Paper & Paperboard Industries 2361
Pennsylvania Electric Co. 2467
Resources Research, Inc., a subsidiary of Hazleton Laboratories, Inc. 2659
Union Carbide Corp. 2606
U.S. Atomic Energy Commission 2682
Wisconsin Electric Power Co. 2592

AIR POLLUTION—1967

MONDAY, MAY 15, 1967

U.S. SENATE,
SUBCOMMITTEE ON AIR AND WATER
POLLUTION OF THE COMMITTEE ON PUBLIC WORKS,
Washington, D.C.

The subcommittee met, pursuant to recess, at 9:55 a.m., in room 4200, New Senate Office Building, Senator Edmund S. Muskie (chairman of the subcommittee) presiding.

Present: Senators Muskie, Bayh, Tydings, Spong, Boggs, and Baker.

Also present: Richard B. Royce, chief clerk and staff director; Leon G. Billings and Richard D. Grundy, professional staff members; and Richard E. Gerrish, minority staff director.

Senator MUSKIE. The committee will be in order.

I am informed that Senator Edward Long of Missouri, who had been invited to testify, is unable to do so. He has sent us the statement he intended to present. It will be placed in the record at this point.

(The statement is as follows:)

STATEMENT OF HON. EDWARD V. LONG, A U.S. SENATOR FROM THE STATE OF MISSOURI

Mr. Chairman, when your Subcommittee met in St. Louis recently to consider the problems of effective control of interstate air pollution, I appreciated the opportunity to submit a statement indicating my concern over the difficulties being encountered in reaching an agreement acceptable to all parties concerned.

Now that your Subcommittee has opened hearings on S. 780, the proposed Air Quality Act of 1967, I would like to comment again relative to this problem and direct particular attention to Section 6 of the bill which pertains to the creation of Regional Air Quality Commissions.

Missouri has two metropolitan areas in which the problem of interstate air pollution has been recognized, Kansas City and St. Louis. The progress in dealing with conditions in the two areas merits examination in the consideration of S. 780.

Although efforts to control air pollution in the Kansas City area were not actively undertaken until early this year, the progress achieved has been commendable. As a result of conferences among interested parties, a proposed compact has been drafted and is before the legislatures of both Kansas and Missouri. I am advised by the Chairman of the Missouri Air Conservation Commission, Lewis C. Green, that the compact has the support of the Governors of both states, has not aroused opposition from local governments within its jurisdiction, and enjoys qualified support from the Kansas City Chamber of Commerce.

A very important provision in the compact provides for the establishment of a single regional interstate air pollution control authority.

Progress in the St. Louis area presents a much less favorable picture. I had hoped that the many meetings between officials of the air pollution agencies of Missouri and Illinois and the meetings of the Governors of the two states would lead to a resolution of the problems involved in reaching an effective compact. It appears, however, that the basic approaches of the two states preclude agreement.

Missouri is seeking a compact granting the regional commission authority to establish and enforce air quality standards and emission regulations in the bi-state area. This airshed concept regards the atmosphere over the area as a single unit without regard to political boundaries. Such provisions are contained in the Kansas-Missouri Air Quality Compact. The Illinois stand is that the agency should deal only with those problems proven interstate in nature. Such a compact, in my opinion, would be difficult to administer and ineffective in achieving pollution control.

It is clear that we must look to the legislation under study by your Subcommittee for the solution of the situation in St. Louis. While the need for federal participation in the control of interstate air pollution is disappointing, it is necessary since state efforts, although diligent, have not been successful.

It is my sincere hope that your Subcommittee will be able to report a bill which will allow the creation of effective regional commissions when efforts of the states have been unsuccessful. I am particularly interested in provisions which would allow regional commissions to undertake primary enforcement activity. St. Louis and many similar areas need a bill which will permit the establishment of a commission having sufficient powers to deal with the hazards presented.

Senator MUSKIE. Our first witness this morning is Dr. Edward T. Blomquist, Associate Director for Standards and Criteria Development, National Center for Air Pollution Control of the Public Health Service.

Good morning, Dr. Blomquist. It is a pleasure to welcome you.

Dr. BLOMQUIST. It is a pleasure to be here.

Senator MUSKIE. We look forward to you for some enlightenment.

STATEMENT OF DR. EDWARD T. BLOMQUIST, ASSOCIATE DIRECTOR FOR STANDARDS AND CRITERIA DEVELOPMENT PROGRAMS, NATIONAL CENTER FOR AIR POLLUTION, PUBLIC HEALTH SERVICE, U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE; ACCOMPANIED BY DR. JOHN T. MIDDLETON, DIRECTOR, NATIONAL CENTER FOR AIR POLLUTION CONTROL; THOMAS F. WILLIAMS, CHIEF, OFFICE OF LEGISLATIVE AND PUBLIC AFFAIRS; AND DR. JOHN H. LUDWIG, ASSOCIATE DIRECTOR FOR CONTROL TECHNOLOGY RESEARCH AND DEVELOPMENT, NATIONAL CENTER FOR AIR POLLUTION CONTROL

Dr. BLOMQUIST. Last month, Dr. Middleton stated here that the recent reorganization of the National Center for Air Pollution Control allows us to more effectively meet the specific responsibilities assigned us by the Congress to develop criteria and standards.

In the past, criteria were the responsibility of one group and standards the responsibility of another. The newly created criteria and standards development programs bring together all those activities which have a direct input into the development of both criteria and standards.

Specifically, the reorganization brings together the staff responsible for research on the effects of air pollution, and the staff responsible for the air sampling networks with the staff responsible for preparing the criteria and standards documents. Data provided by those conducting research are essential in the analysis and evaluation of the effects

of pollutants at varying concentrations needed for air quality criteria and for standards.

Data provided by those operating the sampling networks in turn are essential to all epidemiological and field research on the effects of pollutants.

AIR QUALITY CRITERIA AND STANDARDS

Air quality criteria summarize what is known about the effects of pollutants in the atmosphere. Expressed in terms of pollution concentrations and duration of exposure, they describe the relationships between air pollutants and effects on health, vegetation, materials, visibility, and other aspects of public welfare.

Criteria indicate the lowest level of exposure at which specific deleterious effects have been reported. This means that the criteria will reflect evidence pertaining not only to so-called normal, healthy adults, but also to those individuals and groups—such as the very young, the elderly and impaired—who may be particularly sensitive to certain effects of air pollution.

Hence, criteria provide a realistic base on which State and local air pollution agencies can set their air quality standards. Criteria also provide a realistic base for establishing emission standards which limit the amount of pollutants which can be emitted from various sources.

To accelerate progress in this area, as I have said earlier, we have established a new branch exclusively assigned to develop criteria and standards. Work is underway to develop criteria for carbon monoxide, particulates, the nitrogen oxides, and hydrocarbons.

We have prepared, but not published, criteria for the photochemical oxidants. On March 23, 1967, the Secretary published a 176-page report on the "Air Quality Criteria for Sulfur Oxides," which is one of the most pervasive groups of pollutants in the United States today.

The 1965 Amendments to the Clean Air Act empower the Secretary to regulate emission of pollutants from new motor vehicles and emissions from Federal facilities. Federal standards have been promulgated for these two areas, and these have been reported to you by Mr. Griswold.

Under the new reorganization which Dr. Middleton described, criteria and standards setting responsibility will be carried on under my direction. I should like to take a few minutes to describe some of the work which has been conducted and new work we plan to carry out in this area.

Proposed standards for control of evaporative losses from the fuel system of gasoline-powered automobiles and small trucks applicable to the 1969 model year were published February 4, 1967; final standards may be published by June 30, 1967.

In fiscal year 1968, we expect to promulgate more restrictive standards for hydrocarbons and carbon monoxide for exhausts from automobiles and light trucks. Standards for smoke emissions from diesel buses and trucks, will be set for the 1970 model year. Also, we anticipate standards for hydrocarbon and carbon monoxide will be promulgated for 1970 model gasoline trucks and buses.

In addition, we expect to accelerate our work leading to the improvement of existing standards and the development of new standards for:

(*a*) Hydrocarbons and carbon monoxide in exhaust from all new vehicles.

(*b*) Nitrogen oxides emissions in exhausts from all new vehicles.

(*c*) Odors from new diesel-powered vehicles.

(*d*) Particulates from all new vehicles including smoke and the residues from additives such as lead, barium, and nickel.

As Mr. Griswold pointed out, Executive Order No. 11282 requires that each Federal agency submit a phased and orderly plan for preventing and abating air pollution from the agencies' facilities by July 1, 1967. It is anticipated that these plans will bring to light a number of situations and pollution sources for which existing regulations are not adequate.

There will be need for the development of standards which control a variety of processes carried out in Federal facilities which include metallurgical operations, chemical processes, waste disposal operations, and large fuel-burning installations.

The Criteria and Standards Development Branch will provide consultation to the abatement and control programs concerning initial standards to be recommended for stationary sources in connection with interstate abatement actions and will provide guidance and consultation to Mr. Griswold concerning air quality levels to be used for purposes of determining initial reductions in such interstate abatement actions.

RESEARCH ON EFFECTS

Our research efforts—past, present, and projected—have been primarily devoted to studying the adverse effects of air pollution on human health. Our health studies, in addition to their intrinsic value, also serve as a major source of input for our criteria.

Conversely, our criteria reports serve as feedbacks for our research program planning; they pose the questions which must be answered to permit gradual refinement of the criteria and thus point out the specific areas in which additional research is needed.

The criteria report on the sulfur oxides provides a good example of input derived from our search. Our knowledge of excess morbidity and mortality related to ambient levels of sulfur dioxide was measurably increased by the findings of our studies made in the many-faceted Nashville, Tenn., project.

The hospital admissions study in the Los Angeles area further contributed to the knowledge of the effects associated with exposure to community levels of sulfur dioxide.

Contracts recently awarded to evaluate the effects of the Thanksgiving Day New York City air pollution episode of last year will allow us to update and further document the health effects assembled in our recently published criteria. There were many other studies, including animal laboratory studies under controlled conditions, which provided important new information on the health effects of the sulfur oxides.

For effects other than those on human health, research which we supported increased our knowledge of the effect of the oxides of sulfur on vegetation and on dyed fabrics, and of other damage to materials.

The primary goal of our biological research program thus far has been to determine with increasing precision the quality of air needed to eliminate the threat to the health and well-being of man from pollution arising from the combustion of coal and oil and pollution emitted from motor vehicles.

Of the total health research effort conducted or supported by the Federal Government, by far the major research activity has been devoted to the health effects of sulfur dioxide, particulates, oxidants, and oxides of nitrogen. These are some of the significant products of combustion and the use of the automobile.

We have previously made reference to the contribution made by our research to the satisfactory development of the criteria for the oxides of sulfur. Our research effort similarly is designed to make an important contribution to the development of other criteria reports.

The large number of epidemiological and statistical studies have up to now been almost wholly focused on evaluating the extent of damage due to exposure to these pollutants. These epidemiological studies have often involved large undertakings with substantial investments in manpower, money, and time. Clinical and laboratory studies have stressed the mode of action of these pollutants in very large measure.

Among the earliest studies supported by the Public Health Service which involved human exposure to air contaminants have been those which utilized sulfur dioxide and sulfur dioxide plus a variety of particulates. Other long-term clinical projects have involved the exposure of emphysematous individuals to ambient Los Angeles and filtered air.

The pollutants of interest are those associated with photochemical smog. A large number of animal studies have also been conducted to supply additional information about the effects of sulfur dioxide, particulates, oxidants, and oxides of nitrogen.

Next year's biologic research activity will feature a range of activities from analysis of the 1966 Thanksgiving Day air pollution episode in cities other than New York, to human exposure to graded doses of one of the major oxidants, ozone, to continued support of the research on the emphysematous individuals previously referred to.

These, and a number of other projects involving humans, will help further our knowledge of the interrelationships between the air pollutants which we have been discussing, other environmental variables, and the health of Americans as reflected in morbidity and mortality.

Additional research on animals involving the potentiation of infectious agents by combined exposure with sulfur dioxide and other pollutants is to be undertaken. A considerable amount of animal research is to be devoted to the synergistic effects of sulfur dioxide, oxides of nitrogen and oxidants.

Because of the increasing concern of the hazard of carbon monoxide, a good deal of effort is to be devoted to this agent singly and in combination with the other pollutants. We have observed that carbon monoxide is capable of impairing visual discrimination and decreasing

mental dexterity. We plan to begin a study of the effects of exposure to carbon monoxide by expectant mothers on the birth weight and survival of their infants. In addition, we are planning to investigate the relationship between automobile accidents and carbon monoxide exposure of drivers.

Our research effort dealing with mixtures of gases and particulates represents an effort to simulate the exposures of man and materials to the actual ambient atmosphere.

To better define the quality of air needed for the preservation of health, our research program next year will begin an intensive program on the effects of health associated with fuel additives. These studies on carbon monoxides and fuel additives will supplement the research effort which will continue on the other pollutants.

Among the substances widely used as fuel additives, tetraethyl lead has been identified as a compound of major concern to the public health. Consequently, we are intensifying our research program on the long-term effects of lead at concentrations commonly found in the ambient atmosphere of urban communities. In addition, we are reviewing the health significance of other commonly used additives such as barium and nickel.

The past year has been devoted to tooling up for a comprehensive research program on the health effects associated with lead. Though our knowledge of the toxicity of this metal dates back to antiquity, our knowledge of the effect of exposure to current ambient levels is extremely limited.

A Lead Liaison Committee has been established to coordinate the research efforts of Government and industry. The Committee includes investigators engaged in lead research from industry and Government and representatives of the American Petroleum Institute and the Lead Industries Association, Inc.

One activity to be initiated during the next fiscal year (1968) involves an examination of the chronic effects of atmospheres contaminated with inorganic lead particulate on animals, including primates. Of special interest is the focus of the study on behavioral alterations and changes in the blood of monkeys.

Another animal study involves the interaction of lead with common pollutants found in the ambient atmospheres of cities. This is part of a larger study in which some of these pollutants will be studied separately and in various combinations.

Also, it is planned to expose rats to graded concentrations of inorganic lead particulates. This holds great promise for establishing a relationship between ambient lead levels and the body burden of lead.

Work is in progress on a resurvey of the Wenatchee Orchard workers exposed to lead arsenate over a period of more than 20 years.

Besides the lead studies already discussed, studies of other fuel additives are also in progress. Toxicity studies of barium particulate or gaseous compounds emitted from diesel engines using a barium additive to suppress smoke, will be undertaken. These animal studies necessarily require at least 2 years if sound judgment regarding the chronic effects of a barium additive is to be made. Although the car-

cinogenicity of nickel carbonyl is well known, animal work will be directed to the toxicological properties of nickel alone and in combination with carbon monoxide.

Under Dr. Ludwig's leadership, a technical fuel additive evaluation program covering distillate and residual fuel additives is scheduled to start screening selected combustion fuel additives during the next fiscal year.

Work is also in progress on other diesel additives to suppress odor and smoke from exhaust emissions.

An air testing program for lead, nickel, and barium particulate samples on heavily traveled streets in addition to carbon monoxide and hydrocarbons is in progress using equipment mounted in a motor trailer. The mobility of this specially designed equipment will allow many more cities to be resurveyed and will provide a better evaluation of the contribution of vehicular traffic to the levels of selected pollutants.

AIR MONITORING PROGRAM

The mission of the Center to work towards cleaner air for the people of the United States is aided considerably by our air monitoring systems. Our ability to establish scientifically sound criteria and meaningful standards heavily depends on the data provided by these programs.

The value of air sampling networks to air pollution control, in a real sense, can be compared to the value of vital statistics to a categorical disease control program.

The functions of our air sampling networks are:

(1) To identify air pollutants.

(2) To determine the severity, extent, and characteristics of the air pollution problem.

(3) To determine the sources of pollutants.

(4) To determine the effectiveness of control efforts.

A brief review of the activities of the program will throw further light on these functions.

Our Air Quality and Emissions Data Branch is responsible for the Center's air surveillance program. Its field activities are carried out through the National Air Surveillance Networks (NASN), which are sampling networks for suspended particulate and gaseous pollutants.

The suspended particulate stations and the majority of the gas sampling stations are relatively simple stations which obtain periodic integrated 24-hour samples. Six major gas sampling stations, which constitute the continuous air monitoring program (CAMP), provided full-time information on the minute-by-minute fluctuations of gaseous pollutants of major importance.

Our knowledge of air quality has increased significantly since our first major air sampling networks were established. In fiscal year 1954, there were 10 sampling stations, and now we have 172 federally operated stations.

As a result of field and laboratory demonstrations of techniques, the training of State and local personnel, and the availability of program grants, there has been a sevenfold increase from the 28 State and local stations which independently contributed information for our publications in 1964 to some 200 stations in 1967. In 1968, we expect to receive such information from 300 stations in over 200 communities, to augment our 172 stations. The number of areas on which we have suspended particular information has grown from 289 in 1964 to 485 in 1967.

Since 1964, we have doubled the number of cities on which we have sulfate and nitrate information (97 to 196). We are now able to do analyses on all NASN stations in a given year and in 1968 expect to obtain samples from selected State and local stations for such analysis.

There has been a 30-percent increase since 1964 in the number of communities on which we have data on 17 metals of biologic significance. Through use of our bank of samples from previous years, we have also developed such information on 49 cities for the periods prior to and subsequent to 1961. This information will be used in 1968 to determine the trend of such metals in the air.

Furthermore, improved analytical techniques developed in 1966 and 1967 have allowed us to determine the background concentrations of such metals at 33 rural sites. During 1968, we hope to provide data on all federally operated stations. Improved laboratory techniques will also allow us to routinely report information on benzo (a) pyrene and fluorides.

In 1964, we operated 30 simple gas stations for 24-hour-average samples of sulfur dioxide and nitrogen dioxide. This number had increased to 50 by 1967 and we were field testing methods for ammonia, aldehydes and oxidants. In 1968, we plan to operate 100 of these stations, which will sample for all five gases. Automated laboratory analytical techniques developed in the past 2 years have done much to make this expansion possible.

The continuous air monitoring program was established in 1962, with six complex stations, sampling for sulfur dioxide, nitric oxide, nitrogen dioxide, total oxidant, carbon monoxide, and total hydrocarbons. By the summer of 1967, in great part as a result of our pioneering, some 25 State and local agencies will be employing such continuous sampler analyzers.

During 1967, we experimented with the use of continuous methane analyzers, which in conjunction with total hydrocarbon analyzers give us better estimates of the ambient levels of the reactive hydrocarbons. We will complete our equipping of all our stations with the methane analyzers and improved sulfur dioxide analyzers by 1968.

Over the past year, we have been laying special emphasis on the definition of carbon monoxide exposures in our urban areas. By July of 1967, we shall have completed our sampling of commuter exposures to carbon monoxide in 16 cities, which will represent every major

portion of the Nation. By July, we also hope to have completed our study of carbon monoxide in buildings which occupy air-rights space over major roadways. Beginning in July 1967, such information will be used in refining projections of carbon monoxide 20 years hence.

Furthermore, instruments developed during 1967 will be used in special studies of the carbon monoxide exposure problems of taxicab drivers, patrol car policemen, and similar groups.

The availability of air quality information from the NASN and CAMP has been of crucial importance in evolving and testing concepts of air conservation—including the development of mathematical diffusion models for air pollutants, the relationship of peak concentrations to mean concentrations, the evaluation of populations at risk, and the development of information on causative interrelationships between emissions and air quality. We are pleased with the progress made, but we still need to expand and improve our air sampling program. Next year we plan to concentrate our efforts in three areas.

First, we plan to increase the number of testing sites and the quality of air sampling in the standard metropolitan areas. These are communities in which some 120 million Americans reside and where the air pollution problem is more acute, yet where, even today, most sampling is limited to a single site.

Two, we plan to create a computerized national data bank for systematic recording and analyses of air quality information. The beginning of such a bank will be a reality by July 1967. The detailed information on air which the bank will supply with similar information on water, soil, food, and so forth, will be of primary importance not only to the planned management of our air resources but will be important in defining the effects of pollution on our total ecology.

Three, we plan to strengthen our efforts to inventory the nationwide emissions of air pollutants and the status of control of their sources. We expect to complete the initial inventory in the standard metropolitan statistical areas in the next 2 years.

I hope this report has provided an insight into the activities of the standards and criteria development programs and I shall be happy to answer questions you may wish to raise.

Thank you.

Senator MUSKIE. Thank you, Dr. Blomquist.

There is a distinction between the air sampling program and your continuous air monitoring programs, is there not?

Dr. BLOMQUIST. Yes, sir.

Senator MUSKIE. Is it possible to have a list of the indications where we have the federally operated air sampling networks and also the locations where the States and communities have established such networks?

Dr. BLOMQUIST. I would be glad to supply that.

(Subsequently Dr. Blomquist supplied the following information:)

A Summary of Air Sampling Stations—1966

The attached tabulation consists of Federal, State and local non-continuous sampling stations which were operated in 1966.

[S.P.—24 hour suspended particulate hi-volume samples; G.—24-hour gaseous analysis by NASN; L.—Lead peroxide sulfation rate, 1 month; effects—Abatement branch effects network; *—Indicates station failed to meet criteria for collection of valid samples]

Stations	S.P.	NASN G.	L.	Effects	State and local S.P. stations
Alabama:					
Birmingham	X				
Gadsden	X				
Mobile	X				
Alaska: Anchorage	X				
Arizona:					
Davis Dam				X	
Douglas				X	
Grand Canyon National Park	X				
Nogales				X	
Paradise Valley	X				
Phoenix	X				
Tucson	X		X		
Yuma				X	
Arkansas:					
Little Rock	X				
Montgomery County	X				
Texarkana	X				
West Memphis	X				
California:					
Bakersfield					X
Burbank	X				
Calexico				X	
Eureka					(*)
Humboldt County	X				
Los Angeles	X				
Monterey					X
Needles				X	
Oakland	X			X	
Pasadena	X				
Redding					(*)
Sacramento					X
San Buenaventura					(*)
San Diego	X				
San Francisco	X				
Santa Ana					X
Santa Barbara					(*)
San Ysidro				X	
South Tahoe				X	
Colorado:					
Denver	X	X		X	
Montezuma County	X				
Connecticut:					
Bridgeport					X
Greenwich				X	
Hartford	X	X			
New Britain					(*)
New Haven	X	X			
Norwich					X
Stamford					(*)
Waterbury					X
Delaware:					
Claymont				X	
Kent County	X				
Newark	X				
Wilmington	X	X		X	
District of Columbia: Washington	X			X	
Florida:					
Apalachicola					(*)
Boca Raton					(*)
Delray Beach					(*)
Florida Keys					(*)
Gainesville					X
Jacksonville					(*)
Lake Worth					(*)
Miami					X
Orlando					(*)
Pahokee-Belle-Glade					(*)
Panama City					(*)
Pensacola					(*)
Riviera Beach					(*)

A SUMMARY OF AIR SAMPLING STATIONS—1966—Continued

Stations	S.P.	NASN G.	L.	Effects	State and local S.P. stations
Florida—Continued					
Royal Palm Beach					(*)
St. Petersburg					X
Tallahassee					(*)
Tampa				X	X
West Palm Beach					(*)
Winter Haven					(*)
Georgia:					
Albany					(*)
Atlanta	X				
Augusta					X
Brunswick					(*)
Columbus					X
Gainesville					(*)
Lyons					X
Macon					X
Rome					X
Rossville					X
Savannah					X
Valdosta					X
Hawaii: Honolulu	X				
Idaho:					
Boise	X		X		
Butte County	X				
Coeur d' Alene				X	
Lewiston				X	
Illinois:					
Alton					(*)
Argo					X
Aurora					(*)
Blue Island					X
Calumet City				X	X
Chicago	X			X	
Chicago Heights					X
Cicero					X
Crete					(*)
East St. Louis				X	X
Flossmoor					X
Franklin Park					X
Granite City					(*)
Harvey					X
Hennepin				X	(*)
Hillside					X
Island Lake					(*)
Joliet					(*)
Lake Bluff					(*)
Lockport					(*)
Mokena					(*)
Moline				X	X
Monee					(*)
Midlathian					X
Niles					X
Orland Park					X
Palatine					X
Peoria					(*)
River Forest					X
Rockdale					(*)
Rockford					X
Rock Island				X	(*)
Romeoville					(*)
Springfield					X
Wheaton					(*)
Wilmette					X
Wilmington					(*)
Winnetha					(*)
Indiana:					
East Chicago	X	X		X	
Evansville		X		X	
Hammond	X			X	
Indianapolis	X	X			
Jeffersonville				X	
Morgan-Monroe State Forest	X	X			
Muncie	X				
New Albany	X	X			
Park County	X				
South Bend	X				
Tell City				X	
Terre Haute	X				

A SUMMARY OF AIR SAMPLING STATIONS—1966—Continued

Stations	S.P.	NASN G.	L.	Effects	State and local S.P. stations
Iowa:					
Davenport	X			X	
Delaware County	X				
Des Moines	X	X			
Dubuque	X		X		
Kansas:					
Kansas City	X			X	
Overland Park				X	
Wichita	X				
Kentucky:					
Ashland	X		X	X	
Covington	X	X			
Frankfort				X	
Hawesville				X	
Louisville	X		X	X	
Owensboro				X	
Louisana: New Orleans	X				
Maine:					
Acadia National Park	X				
Portland	X				
Maryland:					
Baltimore	X	X			
Calvert County	X		X		
Massachusetts:					
Brockton					X
Lawrence					X
Lowell					X
New Bedford					X
Springfield					(*)
Michigan:					
Detroit	X	X		X	
Lansing					X
River Rouge				X	
Minnesota:					
Duluth	X			X	
Minneapolis	X	X			X
Moorhead	X				
St. Paul	X		X		
Mississippi:					
Jackson	X		X		
Jackson County	X				
Missouri:					
Kansas City	X	X		X	
Independence				X	
St. Louis	X	X		X	
Shannon County	X				
Montana:					
Deer Lodge					(*)
East Helena					(*)
Galen					(*)
Garrison					(*)
Glacier National Park	X				
Helena	X				
Laurel					(*)
Opportunity					(*)
Nebraska:					
Omaha	X		X		
Thomas County	X				
Nevada:					
Boulder City				X	
Incline Village				X	
Las Vegas	X		X		
White Pine County	X		X		
New Hampshire:					
Concord	X		X		
Coos County	X				
New Jersey:					
Camden	X	X		X	
Elizabeth				X	
Glassboro	X	X			
Jersey City	X	X			
Marlton	X	X			
May's Landing				X	
Newark	X	X			
Penns Grove				X	
Perth Amboy	X			X	
Trenton	X			X	

A SUMMARY OF AIR SAMPLING STATIONS—1966—Continued

Stations	S.P.	NASN G.	L.	Effects	State and local S.P. stations
New Mexico:					
Albuquerque	X				
Anthony				X	
Dulce				X	
Farmington				X	
Rio Arriba County	X				
Shiprock				X	
Sunland Park				X	
New York:					
Akron					X
Albany				X	X
Babylon					X
Big Flats					(*)
Binghamton				X	(*)
Brookhaven					X
Brooklyn				X	
Buffalo		X		X	X
Cape Vincent	X				
Catlin					(*)
Cheektowaga					X
Clarkstown					X
Cohoes					(*)
Colesville					(*)
Colonie					(*)
Duanesburg					X
East Greenbush					X
Ellenville					X
Elmira					(*)
Endicott					X
Grafton					X
Grand Island					X
Holland					X
Horseheads					X
Hudson					X
Irondequoit					(*)
Islip					X
Johnson City					(*)
Kingston					X
Lackawanna					X
La Grange					X
Lockport					X
Massena					X
Miniola				X	
Mount Vernon					X
New Platz					X
New Rochelle					X
New York	X	X			
Niagara Falls				X	(*)
Niskayuna					X
Ossining					X
Petersburg				X	
Philmont					X
Poughkeepsie					X
Riga					(*)
Rochester					X
Saugerties					X
Schenectady					X
Sloan					X
Smithtown					X
Somers					X
Southampton					X
Southold					X
Staten Island				X	
Syracuse					X
Tonawanda					X
Troy					X
Utica					X
Watervliet					(*)
Webster					(*)
White Plains				X	X
Yonkers					X
North Carolina:					
Cape Hatteras	X				
Charlotte	X		X	X	
Durham					(*)
Morgantown					(*)
New Bern					(*)
Waynesville					(*)
Williamston					(*)
Wilmington					(*)

A SUMMARY OF AIR SAMPLING STATIONS—1966—Continued

Stations	S.P.	NASN G.	L.	Effects	State and local S.P stations
North Dakota:					
Bismarck					X
Fargo					X
Ward County					X
Ohio:					
Adams County (West Union)					(*)
Akron	X				
Athens					(*)
Canton					X
Carrollton					(*)
Cincinnati	X			X	
Clermont County (Batavia)					(*)
Cleveland	X		X		
Columbus	X			X	
Dayton	X	X			
East Liverpool					X
Findlay					(*)
Franklin					X
Greenville					X
Hamilton					X
Ironton				X	
Lima					(*)
Lorain					X
Marietta				X	
Marysville					X
Napoleon					X
Newark					X
New Lexington					(*)
Noble County					(*)
Painesville					X
Port Clinton					(*)
Portsmouth					X
St. Clairsville					X
Steubenville				X	X
Toledo	X			X	
Upper Sandusky					(*)
Van Wert					(*)
Warren					X
Washington Court House					(*)
Wooster					X
Youngstown	X	X		X	
Oklahoma:					
Cherokee County	X				
Oklahoma City	X	X			
Tulsa	X				
Oregon:					
Columbia County					(*)
Cowallis				X	
Curry County	X				
Portland	X	X		X	
Ranier				X	
The Dalles				X	
Pennsylvania:					
Chester				X	
Clarion County	X				
Easton				X	
Lancaster	X		X		
Philadelphia	X			X	
Pittsburgh	X	X			
Reading	X				
Sharon				X	
Warminster	X	X			
West Chester	X	X			
Puerto Rico:					
Bayamon	X				
Guayanilla	X	X			
Ponce	X				
San Juan	X	X			
Rhode Island:					
Providence	X	X			X
Washington County	X				
South Carolina:					
Aiken					(*)
Anderson					(*)
Beaufort					(*)
Chaplin					(*)
Columbia	X		X		
Florence					(*)
Greenville	X				
Greenwood					(*)
Lancaster					(*)
Richland County	X				

A SUMMARY OF AIR SAMPLING STATIONS—1966—Continued

Stations	S.P.	NASN G.	L.	Effects	State and local S.P. stations
South Carolina—Continued					
Rock Hill				X	X
Spartanburg					(*)
West Columbia					(*)
South Dakota:					
Black Hills Forest	X				
Sioux Falls	X				
Tennessee:					
Chattanooga	X	X			
Memphis	X		X		
Nashville	X	X			
Texas:					
Austin					X
Baytown					(*)
Beaumont					(*)
Chambers County					(*)
Clute					X
Corpus Christi					X
Dallas	X				
El Paso		X		X	X
Fort Worth					X
Fredricksburg					X
Galveston					X
Groves					(*)
Harlingen					X
Houston	X				
Laredo					(*)
Lubbock					X
Matagorda County	X				
McAllen					X
Odessa					X
Orange					X
Port Arthur					X
San Antonio	X				(*)
Texarkana					X
Texas City					X
Tyler					X
Waco					X
Wichita Falls					X
Utah:					
Ogden	X				
Salt Lake City	X	X			
Vermont:					
Burlington	X		X		
Orange County	X				
Virginia:					
Danville	X				
Norfolk	X				
Shenadoah National Park	X		X		
Washington:					
Bellingham				X	(*)
Clarkston				X	
Cowlitz County					(*)
Everett					X
Kelso					(*)
Longview				X	(*)
Pullman				X	
Seattle	X	X		X	(*)
Spokane				X	(*)
Tacoma					X
Vancouver				X	X
West Virginia:					
Charleston	X	X			
Huntington				X	X
Parkersburg				X	X
Weirton				X	
Wheeling				X	X
Wisconsin:					
Door County	X				
Eau Claire					X
Kenosha				X	X
Madison					X
Milwaukee	X	X			
Racine					X
Superior				X	X
Wyoming:					
Cheyenne	X				
Yellowstone National Park	X				
Total	136	40	19	95	136
Sampling did not meet established criteria*					102

A SUMMARY OF CONTINUOUS MONITORING—1966

Alabama: Birmingham
Arizona: Phoenix
California:
- State of California
- Los Angeles County
- Orange County
- San Bernardino
- San Francisco (Bay Area APCD)

Colorado:
- State of Colorado
- Denver (CAMP)

Connecticut: State of Connecticut
District of Columbia:
- District of Columbia (CAMP)

Florida: State of Florida
Georgia: State of Georgia
Illinois:
- City of Chicago
- Chicago (CAMP)

Kentucky:
- State of Kentucky
- Louisville

Maryland: Baltimore
Massachusetts: State of Massachusetts
Michigan: State of Michigan, Detroit
Missouri:
- Jefferson County
- St. Louis
- St. Louis (CAMP)

Nevada: Las Vegas
New Jersey: State of New Jersey
New York:
- State of New York
- New Rochelle
- New York

North Carolina:
- State of North Carolina

Ohio:
- Akron
- Cincinnati (CAMP)

Oregon: Portland
Pennsylvania:
- State of Pennsylvania
- Philadelphia
- Philadelphia (CAMP)

Texas: State of Texas
Washington: State of Washington
Wisconsin: Milwaukee

Senator MUSKIE. Now, when you speak of a network or a station, how extensive is that? You spoke of 172 federally operated stations. Does this mean 172 sites?

Dr. BLOMQUIST. Yes, sir.

Senator MUSKIE. 172 sites?

Dr. BLOMQUIST. Yes. That is, it would be different sites.

Senator MUSKIE. Now, would that be in 172 different communities?

Dr. BLOMQUIST. In the main, it would. There could be one or two in the same community. I cannot say right offhand that all of them are in a different city but most of them are.

Senator MUSKIE. So, it gives us only the benefit of a single site in the cities in which they are located.

Dr. BLOMQUIST. This has been one of our problems. The number of testing sites within a community has been too limited.

Senator MUSKIE. So, we ought to have multiple sites in given communities?

Dr. BLOMQUIST. That is one of our intentions. One of our major emphasis in the next year will be to increase the number of sampling sites in the large communities.

Senator MUSKIE. Now, in given communities is there a duplication of Federal sites and State and community sites?

Dr. BLOMQUIST. We feel that duplication is not a serious problem at all.

Senator MUSKIE. I was suggesting it not to suggest a duplication problem but to give some impression of the extent to which the Federal stations may be supplemented by State and community stations. Are they to any extent?

Dr. BLOMQUIST. Yes. As time has gone on, both the State and locals have added stations and the information is being collected and analyzed for all. We are pleased.

Senator MUSKIE. So, there is a coordination effect?

Dr. BLOMQUIST. Very much.

Senator MUSKIE. Now, is your air monitoring program conducted by these same installations or are they——

Dr. BLOMQUIST. They are operated by the same group. Within centers.

Senator MUSKIE. Within centers?

Dr. BLOMQUIST. Yes; there is coordination. The continuous air monitoring program is much more detailed: it reports the information, as I indicated, minute by minute; whereas the other one is a cruder type of analysis, giving us data periodically.

Senator MUSKIE. For continuance, programs are more sophisticated?

Dr. BLOMQUIST. Much more sophisticated.

Senator MUSKIE. Is that tied in multiple sites, or single sites?

Dr. BLOMQUIST. This, too, is more nearly single sites.

Senator MUSKIE. Now, it is my impression, and I would like you to correct me if I am wrong, that the single site installation does not help much in determining or in establishing air quality criteria for the community which is served only by a single site.

Dr. BLOMQUIST. It gives limited information. It is our hope that we can relate a sample taken at one place, through mathematical models, to what is happening other places.

Senator MUSKIE. To what extent can you use a single site installation to establish emission standards for particular industries in the community served by the single site?

Dr. BLOMQUIST. There will be limitations.

Senator MUSKIE. What policy does the Department have relative to recommending the establishment of emission standards in communities which are served by one of these single site sampling stations?

Dr. BLOMQUIST. I am sorry.

Senator MUSKIE. What can you do as a practical matter in the community that is served by a single air monitoring, air sampling installation? What as a practical matter can you do to control stationary emission sources?

Dr. BLOMQUIST. We will have to have additional points of measurements. We will have to measure at the sources of emission.

Senator MUSKIE. So that a community which is served by a single installation is not yet ready, in your judgment, to establish emission standards for industry?

Mr. WILLIAMS. May I add something there, Mr. Chairman?

Senator MUSKIE. Yes, sir.

Mr. WILLIAMS. We encourage these communities and States, of course, to supplement our sampling with their sampling. Most large cities have sampling network installations beyond ours.

Senator MUSKIE. I am stating my impression of the testimony thus far.

Before a community can get effective emission standards relating to stationary sources, it must be served by a wider range air monitoring or air sampling network than a single site can provide?

Mr. WILLIAMS. It would be desirable but there are other ways of getting a pretty good notion of what the ambient concentrations of pollution might be.

Senator MUSKIE. What are the other ways?

Mr. WILLIAMS. Through source inventory and meteorological data.

Senator MUSKIE. To what extent have communities in this country that established air quality criteria tried to control the stationary sources? What communities have done this?

Dr. BLOMQUIST. Ambient air quality criteria?

Senator MUSKIE. Tied to control emissions from stationary sources.

Dr. BLOMQUIST. The State of California.

Dr. LUDWIG. Well, I think the State of Oregon has some air quality standards.

Mr. WILLIAMS. New York State.

Dr. LUDWIG. New York State does. The State of Colorado or the city of Denver and the county of Denver have such standards.

Senator MUSKIE. Is this a complete list?

Mr. WILLIAMS. Yes.

Dr. LUDWIG. Yes.

Senator MUSKIE. So it is very limited.

Dr. LUDWIG. Yes.

Senator MUSKIE. What have been the obstacles to more rapid progress?

Mr. WILLIAMS. Well, I don't think State——

Senator MUSKIE. Money, the authority to establish monitoring stations and air sampling networks?

Mr. WILLIAMS. I believe one of the first things that State and local governments do with the Federal assistance they receive is to improve their sampling operations but they have not yet on the whole improved them enough to get the kind of data that you are talking about and to establish air quality standards.

Senator MUSKIE. Can we get anything for the record to show the extent to which the Federal funds authorized under the Clean Air Act have been used for this purpose?

Mr. WILLIAMS. Yes, sir.

Senator MUSKIE. Can we get that?

Mr. WILLIAMS. Yes.

(Subsequently Mr. Williams submitted the following information:)

In Fiscal Years 1965 and 1966, a total of $10,750,000 was available for air pollution control program and survey grants to local, State, and regional agencies. Of this amount, $2,700,000 were budgeted by grantee agencies for purchases of equipment and supplies needed for air sampling activities. Thus, about 25 percent of grant funds were earmarked for this purpose. Through May 1967, $5,380,000 were awarded to local, State, and regional agencies from Fiscal 1967 funds (the remainder of the $8,480,000 available for grants will be awarded during the month of June). Of the amount awarded through May 1967, the sum of $940,000 was budgeted by grantees for air sampling equipment and supplies. This represents 17 percent of funds awarded up to that time.

(Details were previously submitted in connection with testimony on April 19, 1967.)

Dr. BLOMQUIST. I think another point is the absence of criteria and hence the emphasis we are trying to give this coming year to criteria for other pollutants.

Senator MUSKIE. I think the point has been made that a community cannot really move to control emission standards within its boundaries unless it has done something fairly effective by way of establishing ambient air quality criteria. Is that a legitimate assumption?

Mr. WILLIAMS. No; not necessarily, Mr. Chairman.

Senator MUSKIE. All right.

Mr. WILLIAMS. Emission standards can be based on less definitive knowledge than you would need to determine the complete air pollution picture, so to speak, of any given airshed. Emission standards can be based on knowledge that is already available about the effects on health and welfare of certain gross sources of pollution. It would be desirable and it would be a good thing to reach the sophisticated level of control that would allow us to control all sources of pollution in accordance with ambient air criteria and ambient air standards, but for the most part and with regard to many important sources of pollution, technology that is now available would not allow it anyway.

Senator MUSKIE. Are you saying that some sources of pollution which are the basis of known effects upon health are so obvious and gross that you ought to move to control them?

Mr. WILLIAMS. Yes, sir.

Senator MUSKIE. Whether or not an ambient air quality program has been established in the community?

Mr. WILLIAMS. Yes, sir. In our experience with regard to many sources of pollution, if you control them to the extent to insure that they, in and of themselves, would not damage health and welfare, you would be controlling them to the full extent possible considering the current stage of the development of technology for control.

Senator MUSKIE. If this is or should be the public policy (1) to take care of the obvious gross, stationary sources of pollution by controls prior to the establishment of ambient air quality criteria; and (2) to establish further controls or wider ranging controls: What is the magnitude, in your judgment, of the two sources or air pollution in our large metropolitan areas? The gross sources and then the lesser sources?

Mr. WILLIAMS. Well, we believe that both are important and we believe both directions you have outlined should be traveled.

I believe our previous testimony has indicated that we believe that certain interstate sources of pollution, gross sources of pollution, so to speak, should be controlled to the extent required by minimum Federal standards now, on the basis of the damage that they will do, in and of themselves, to health and welfare.

Senator MUSKIE. What kinds of sources fall in each of the two groups, gross sources or the lesser sources—gross sources being sources that ought to be dealt with as far as we can get the technology?

Mr. WILLIAMS. Yes, sir——

Senator MUSKIE. And independent of the ambient air quality criteria, and the lesser sources to be taken care of after we have developed the ambient air quality criteria. What kinds of sources fall within the two categories?

Mr. WILLIAMS. I believe in previous testimony we outlined some of these. They are large sources—metallurgical operations, paper and pulp, for instance, chemical, powerplants, the large sources, I might say, that are, on the whole, most readily controlled, considering the relative amounts of pollution they put out and which do, in and of themselves, adversely affect health and welfare.

Senator MUSKIE. When we deal with these sources, we are talking about a different kind of criteria for different pollutants as contrasted with ambient air quality criteria. Could we get from you, Mr. Blomquist, or anyone else a distinction relating to specific kinds of pollution emissions and the criteria relating to the quality of ambient air? Is there a distinction between the two that has any meaning or are they really the same thing?

Mr. WILLIAMS. They are the same thing insofar as you are measuring the effects of a given type of pollutant on people and property. They are the same in that regard.

Senator BAKER. I wonder if the chairman would yield, so that I might ask a question on that same point.

That is a question that I think has woven its way through these hearings for some time, and it is whether there is a straight line relationship between the concentration of the pollutant of the atmosphere and the biological effect or something other than a straight line response to the discernible biological effect?

Dr. BLOMQUIST. In the case of the sulfur oxide we drew a graph showing the relationship of the efforts plotted against concentration and time. Plotted on a semilogarithmic scale there was a curve relationship between concentration, time, and effects.

Senator BAKER. The steeper grade granting with the higher concentration?

Dr. BLOMQUIST. Yes, sir. We were able to distinguish those exposures in time that were connected with death and those in which serious health effects were reported.

Senator BAKER. So you do have from a practical standpoint two different considerations; that is, the low level of ambient air sample concentrations versus the high concentrations with the non-straight-line relationship between cost and effect?

Dr. BLOMQUIST. We were able to show that for vegetation effects, as well.

Senator MUSKIE. Would you want to return to my question, Mr. Williams, on the distinction between ambient air quality and the criteria relating to the effects of particular pollutants?

Mr. WILLIAMS. Yes, sir. Let me see if I can clarify that a bit.

If you are concerned about, let's say, sulfur emissions from a large facility, the emissions from that facility, disregarding all other sources of pollution, will have adverse effects on health and welfare.

Senator MUSKIE. Independent of its concentrations?

Mr. WILLIAMS. Yes, sir. With regard to the control technology available today, we cannot, without substitution of fuels and such things as that, control sulfurous emissions to the extent necessary to prohibit the effects from a single source. This does not negate the fact that if you have many sources of pollution and you are considering them all, you have an even greater degree of adverse effects.

Senator MUSKIE. Let me ask you something since you have brought up the question of sulfur.

Last week, Mr. Clarke who is one of the representatives of the Central Electricity Generating Board of London, testified here on the development of tall-stack technology, and said this:

Beyond the gross effects one gets from concentrations far in excess of those which you find in the atmosphere, "they"—I can't remember who "they" were, the medical people—have not been able to prove that sulfur dioxide as such is dangerous to health to put it quite bluntly.

I think this is illustrative of the distinction I am trying to make between criteria relating to specific pollutants and the ambient air quality criteria which we are all trying to establish across the country as a means of controlling emission.

Now, Mr. Clarke says that relative to sulfur dioxide you can give concentrations not found in the atmosphere, identify the health effects of such concentrations, but "they have not been able to prove that sulfur dioxide as such is dangerous to health to put it quite bluntly." We disagree with that.

Dr. BLOMQUIST. Our several years' investigation into sulfur dioxide leading to the air quality criteria makes us believe that the sulfur dioxides do have an effect by themselves.

Senator MUSKIE. In condensations that are found in the atmosphere?

Dr. BLOMQUIST. In oxides of sulfur; yes.

Now, we must recognize the fact that the particulates enhance the effect and we have a good explanation of why. Particulates can be an additional pollutant. Further, they can serve as a vehicle by which an absorbed gas can reach the lung.

I think the action of particulates here might be compared to the phenomena we see in the communicable disease field. We know if the tubercle bacilli are attached to droplet nuclei they are much more effectively spread.

Senator MUSKIE. Does this mean that if you eliminate the smoke or the particulate you can reduce the ill effects of sulfur dioxide concentration in the air?

Dr. BLOMQUIST. I think we would find that this would be effective. We feel we must get rid of both.

Senator MUSKIE. Now, I think Mr. Clarke said, and my colleagues on the committee heard his testimony and they can correct me if I am wrong, that in his judgment the elimination of the smoke eliminates the cause of deaths and the epidemic episodes in London.

Dr. BLOMQUIST. Yes; between the two episodes reported in London the difference was greatest in the reduction of particulates. On the other hand, there are other factors that must be considered. One that we have often discussed is the effectiveness of the control measures during the second episode. People were warned earlier. I think there were many other factors that have to be considered than just the difference in particulates.

We are talking about sulfur dioxide as it appears in the atmosphere, and we consider it is a good index. We are not using simply SO_2, but all the common pollutants associated with SO_2.

Senator MUSKIE. Is sulfur dioxide and concentrations found in the air dangerous to health?

Dr. BLOMQUIST. On what basis?

Senator MUSKIE. What is the evidence?

Dr. BLOMQUIST. Well, it was a long evaluation of the many, many references that we reviewed. In the course of reviewing them, we, of

course, evaluated the individual references and those which to us seemed most applicable to the question we were trying to solve.

We have some 96 references relative to health which we thought all contributed to the conclusion that the sulfur oxides were in fact deleterious to health at the various concentrations quoted.

Senator MUSKIE. Did those references include the results mainly researched by the Public Health Service?

Dr. BLOMQUIST. They did.

Senator MUSKIE. Relevant to the sulfur dioxide in the air?

Dr. BLOMQUIST. They did; yes.

Senator MUSKIE. Did those references suggest the minimum concentrations below which we need not be concerned with the effect on health and above which we need to be concerned with the effect on health?

Dr. BLOMQUIST. Yes; this is one of the primary questions we addressed ourselves to. As we indicated in the volume, we were not able to establish a precise point but there were identifiable ranges of values distinguishing concentrations which seemed to have no obvious effect and those with beginning effects.

Senator MUSKIE. So that you are pretty sure in your own mind that you know the concentration of sulfur dioxide in the ambient air above which you ought not to go because of health effects?

Dr. BLOMQUIST. Yes, sir. Of course, it is much easier when we use the higher concentrations when people get sick. The question we are trying to solve is not what value will make all people sick; we are concerned about susceptible people. We do not want them to be subjected to any stress which added to, say, an infection will make the course of their disease worse.

It takes judgment to say at what point we feel the lowest permissible concentration should be.

Senator MUSKIE. In other words, there is a favorably large difference?

Dr. BLOMQUIST. Yes; as we indicated in our graph there it is not a particular point but a range of values.

Senator MUSKIE. On what other specific pollutants do you have a comparable basis of knowledge? Are there any?

Dr. BLOMQUIST. At this point, the sulfur oxides is the one group on which we feel we have the most knowledge because we have done the most work. We are now well along on the oxidants. I think they are the second group of pollutants on which we have the most definitive information.

Senator MUSKIE. Now, do I recall correctly from your statement that you say you have developed criteria dealing with oxidants?

Dr. BLOMQUIST. It is assembled but it is not published. It is under extensive review now.

Senator MUSKIE. Now as to stationary sources which emit sulfur oxide and oxidants, then you would say that they would fall in the first of the two categories which Mr. Williams identified earlier, that is, the category where the health effects are so obvious that you ought to impose controls on stationary sources whether or not you have an ambient air quality criteria? Is that correct?

Dr. BLOMQUIST. I feel that the concentration coming from a single source can produce an effect in the immediate environment. As emissions spread, and accumulate from other sources, they effect the total community.

Senator MUSKIE. So you do have to have some knowledge of the ambient air quality criteria even dealing with this kind of a source?

Dr. BLOMQUIST. Yes.

Senator MUSKIE. Let me ask you this and then I am going to yield to my colleagues who, I am sure have a lot of questions of their own.

With S. 780, we have surfaced the problem of national emission standards for particular interest and I can certainly fully understand the rationale behind it. As a matter of fact, in a community which I recently visited there is quite obviously an inhibiting force being applied by local industry against even an exposure of the problem lest such exposure would redound to the disadvantage of the community.

So, there is an economic pressure that suggests the desirability of national emission standards, but the other side of the problem also is very important to these hearings.

Now, let me ask you this: There was considerable resistance to your proposal to publish the criteria dealing with sulfur dioxide even though they were not mandatory; they were simply advisory. Under the 1963 Clean Air Act the objective was to provide guidelines to States, communities, and particularly metropolitan areas with air pollution problems all with possible health effects of sulfur dioxide. Notwithstanding the fact that these criteria only advised them there was considerable resistance to them because it was felt, I suppose, that the publication would generate a lot of pressure in communities to implement the criteria and to establish controls based upon them. Is that a fairly correct analysis of the nature of the opposition?

Dr. BLOMQUIST. I think so.

I think I should add that for a long time there was misinformation about just what criteria were. I think we are always confronted with the problem of the distinction between criteria and standards.

Senator MUSKIE. Now, if the basis for the national emission standards proposal is that there are certain industries which by their nature ought to be controlled, why would not the purpose be served at least in part if you were to publish criteria dealing with these industries rather than undertake to establish national emission standards?

I am not talking about ambient air quality criteria. I am talking about criteria similar to the sulfur dioxide criteria which will identify for communities across this country the kinds of industries which by their nature have an unhappy and an unfortunate impact upon the health of human beings as well as biological effects relating to plant and animal life.

Have you given consideration to that alternative to national emission standards?

Mr. WILLIAMS. We have thought of it certainly as a supplementary activity. I think some of the same pressures you referred to would persist. I think, when you consider the difficult job the control official has at the State and local levels, that he might, on occasion, find it more feasible to jump on the backyard incinerator and let the steel mill go.

Senator MUSKIE. The problem with the standards, of course, is that once the standard is established it applies to a given industry wherever that industry is located. That eliminates some options perhaps for effective control of air pollution in the heavily polluted areas in the country. But if you publish criteria which clearly identify the health risks associated with particular industries wherever they are located, in your judgment would not that act to stimulate the public opinion which can overcome the kind of pressure that motivates the proposal of national emission standards?

Would it not have that effect, at least on those industries that resisted sulfur dioxide criteria and felt that public opinion of that kind could be a powerful force?

Dr. MIDDLETON. May I respond, Senator Muskie?

Senator MUSKIE. Yes, Doctor.

Dr. MIDDLETON. I think it is best found in the experience of the State of California in which nothing was done about the control of the motor vehicle until, by law, a compulsion had been brought about on the industry to react to the public demand for clean air, such that the standards evolved in California and their emission restrictions became the instrument, shall I say, to bring around the cooperative attitude of industry to respond to California's need.

The Federal position should be no less than that indicated by one of the States, namely, that strength can be given for control purposes once a standard of quality is envisioned.

Senator MUSKIE. It was not the purpose of my question to suggest that national criteria dealing with particular industries should be sufficient in a particular community. Obviously they would have to be implemented by standards in a particular community or region.

The question that I pose is whether or not the publication of the national criteria would not stimulate the development of standards in communities or metropolitan areas which are faced with an immediate problem of control.

Dr. MIDDLETON. Perhaps I missed the thrust of your question; I had not intended to.

The point is that criteria, themselves, have no mandate; they explain a relationship as Dr. Blomquist has told you.

Senator MUSKIE. This I understand.

Dr. MIDDLETON. It is the option of State and local government to respond to this as stated in the present Clean Air Act.

I am suggesting by the example in California—where no criteria were developed—that standards were required to bring about an air quality change. People had known for some time that the motor vehicle was having an adverse effect on health but there had been no response on the part of industry until there had been emission restrictions.

Senator MUSKIE. I still don't think you have answered my question.

Dr. MIDDLETON. I am sorry, sir.

Senator MUSKIE. In saying that I am not being critical, I am probably subject to criticism for not stating my question clearly.

Dr. MIDDLETON. That is rarely so.

Senator MUSKIE. It happens quite often.

You were dealing with the automobile problem, one that did not

respect jurisdictional lines or regional lines and also a product which was manufactured for a national market which ought to be manufactured in some degree of uniformity. The automobile is a somewhat different question. What we are now considering is the question of whether or not we ought to establish national emission standards relating to stationary sources of pollution.

Now, one of the problems with that proposal, at least for me and I think for several members of the committee, is subjecting the plants in the particular industry which by its nature contributes to air pollution to the same degree of control, whether they are located in the heart of a large metropolitan area like New York or in the middle of Death Valley, to pose an extreme case.

Now, when you put it that way, this creates a lot of questions. Among other things, that kind of a policy would seem to prohibit mine mouth generation of electricity as a way of getting away from generation of electricity in the heart of Manhattan. This is one of the things that would seem to make this impossible.

So, what I am suggesting as a possible alternative to resolve this problem is criteria dealing with particular industries which would put communities on warning as to whether or not they have a leper in their midst.

Mr. WILLIAMS. Are you speaking of emission criteria, Mr. Chairman?

Senator MUSKIE. Yes.

Mr. WILLIAMS. Emission criteria?

Senator MUSKIE. Yes.

As to whether or not they have a leper in their midst, and it would seem to me in communities which have the problem, the pressures would be generated which could lead to the development of standards dealing with the region or the community.

It seems to me that this makes sense, at least initially, just like every other proposal you make in the field that is subject to so much debate and controversy that I may back off on it. But I am putting this out as a suggestion hoping that it might prove feasible.

It seems to me it has support in S. 780 because in your proposal for a regional commission you recognize that there is a difference in the intensity of the problem, particularly in metropolitan areas. If you have such a commission set up, whether under the provisions of S. 780 or by contract or otherwise, then it seems to me that the establishment of emission criteria in particular industries would put those authorities on notice that these are the lepers and the problem children. This could generate the public pressures necessary to establish the standards where they are needed in places where there is a problem.

I am stating this proposition simply to test your reaction and to try to get around this problem that is perplexing us at the moment.

Dr. MIDDLETON. Your exposé has clarified the question quite a bit.

You will remember in our earlier testimony, Senator Muskie, we said we would not publish national emission standards until we had determined the relationship of the particular fallouts to health-welfare effects. This seems to be in harmony with what your suggestion may mean.

Senator MUSKIE. So that, in your own proposals the idea I have just put out would be a necessary first step anyway.

Dr. MIDDLETON. Precisely.

Senator MUSKIE. Well, I have other questions but I know that I may have raised points that other members wish to ask.

Senator BAKER. Go right ahead.

Senator SPONG. Go right ahead.

Senator MUSKIE. I might like to have you take it up for a while.

Now, in your testimony you told us, and I quote, "Work is underway to develop criteria for carbon monoxide, particulates, the nitrogen oxides and hydrocarbons."

Dr. BLOMQUIST. Yes, sir.

Senator MUSKIE. These are listed, I take it, because they are the real problem children as you have identified them up to this point.

Dr. BLOMQUIST. Yes; on the basis of the public health problem.

Senator MUSKIE. Now, can the knowledge that you developed and the research you have put in motion to deal with these problems be related to particular industries and, of so, are you doing so?

Dr. BLOMQUIST. Yes; they can be related to certain industries. We know that certain kinds of emissions come out from certain industries; therefore, we have criteria on specific pollutants. There is an obvious relationship.

Senator MUSKIE. So that you have already begun building the body of knowledge upon which you could develop the emission criteria of particular industries?

Dr. BLOMQUIST. Yes.

I might give you an example. If you think of steel mills where we have identified particulate matter and carbon monoxide as the major pollutants, we would need to have criteria for both of these pollutants.

Senator MUSKIE. How precise is the knowledge that you have developed relative to measuring the health impact of these pollutants in concentrations that are found in the atmosphere?

Dr. BLOMQUIST. The only ones I can authoritatively speak about are the sulfur oxides, where we have good information. In the case of the oxidants the data adequately supply us with information for criteria on health, on visibility, materials, and vegetation; I am convinced that the information will allow us to develop criteria for all four parameters. I think as time goes on, some of the pollutants around which we will want to develop criteria—the information may not be adequate to describe the effects on each of the above parameters. I am thinking of the particulates.

Here we have a very miscellaneous group. They will probably take more than a single criteria document. The specific particulate, lead, in my opinion deserves a specific document.

Senator MUSKIE. To what extent has it been possible for you to research action of some of these pollutants with each other in the ambient air?

Dr. BLOMQUIST. I start out again with the example of the sulfur oxides document. There we report the interaction of the various oxides with particulates.

In the case of the oxidants, we will be reporting on the effects of several component parts, one of which will be ozone. Another is what we commonly call the PAN's. Again, the criteria document will de-

scribe a group of pollutants and the interaction, one with the other.

Senator BAYH. Mr. Chairman——

Senator MUSKIE. One other question and I will yield to the Senator.

It seems to me as a layman, and that is all I am in this field, that there can be almost an infinite number of combinations of various pollutants almost requiring a special research job dealing with the interaction of pollutants in the atmosphere in every city with a problem. Is this an overstatement of the attitude and complexity of the problem?

Dr. BLOMQUIST. This is one of the serious problems that people who are conducting research face. There are so many variables the only way they can carry out research is to approach a part of it at a time. We cannot control all the variables.

Senator MUSKIE. So that you try to identify the health impact of each of the specific groups; you are doing some work with respect to produce of the interaction of these pollutants but the magnitude of that one is still pretty undefined, isn't it?

Dr. BLOMQUIST. It is more difficult. This is one of the reasons we rely heavily on epidemiology as a means of getting answers. Epidemiology reports effects as they actually occur in the natural situation.

Senator MUSKIE. So, it would seem to me that you necessarily concentrate therefore upon those regions of the country which have obvious and present air pollution, and you try to identify the elements of those problems before you give consideration to both of them.

Dr. BLOMQUIST. Yes, sir.

Senator MUSKIE. Senator Bayh, I am sorry. I slipped to another question.

Senator BAYH. You have been pursuing this so diligently and have developed a line of extremely helpful evidence here. Please forgive me if I interrupt.

It might be helpful to keep the record consistent here, since we are talking about various specific emission standards and the witness has brought out that there are different ones. We might like to have your opinion about the studies that have been conducted on the particular pollutant of fluoride, especially the fluoride problem as it affects the aluminum industry and how you have had to deal with this one unique type of pollution.

Let us know if you have had the opportunity to check the emission before and after the application of the scientific capability there. We have been told that crops and livestock flourish almost under a smokestack, or at least in close proximity to these large plants, once the pollution problem has been remedied.

If the chairman would prefer for my question to come later, it would be all right with me.

Senator MUSKIE. No; that is fine.

Dr. MIDDLETON. I perhaps could comment having had some understanding of the fluorine problem.

It is quite true in those industries where there is control technology for fluorine compounds, that controls can be brought about so that susceptible crops can be protected.

I would not limit it, Senator Bayh, to solely the aluminum interests. The steel people have likewise been able in the State of Utah, as an

77-515 O—67—pt. 4——3

example, to bring about control such that fluorine levels are reduced to the extent that there is a minimum of injury and no damage to plants and perhaps only slight damage to cattle.

So, once the problem has been identified, then even with these very significant industries, it is possible for the pursuits of agriculture, as you mentioned them, to continue.

Dr. LUDWIG. May I make a comment on the phosphate fertilizer industry?

Senator MUSKIE. Yes, sir.

Dr. LUDWIG. At the present time, we have a cooperative project with the manufacturing chemists to define specific problems with specific manufacturing processes, We have completed reports to date on sulfuric acid and nitric acid. There are some three or four more of these under preparation at the present time. One of these is for the phosphate fertilizer industry.

To answer your question specifically, in these evaluations the effectiveness of the control devices are taken into account. In other words, not only do we collect data that is available from industry but we carry on a sampling program of additional industrial plants to check out the effectiveness of the control devices that are available in these various industries.

Senator BAYH. I thank the Chair for yielding.

Senator MUSKIE. I would like to ask a few questions here on this slightly different subject.

Dr. Middleton in his statement referred to air quality criteria developed by the States of California and New York.

Now, what, in your opinion, is the technical validity of those criteria? Are they sound?

Also, while you are on that subject, how do they differ, for example, with respect from the criteria you have developed?

Dr. MIDDLETON. I hate to confuse the issue; still, so far the State of California has not developed criteria. Their standards are somewhat descriptive and maybe they cloud the criteria issue; let's assume for our discussion that they are criteria, for comparison.

Senator MUSKIE. First let's establish the point that you have raised.

You say that California and New York have not established air quality criteria?

Dr. MIDDLETON. They have established air quality standards in the State of New York and the State of California—ambient air quality standards.

Senator MUSKIE. They are not related to criteria?

Dr. MIDDLETON. I beg your pardon, sir.

Senator MUSKIE. Are they unrelated to criteria?

Dr. MIDDLETON. They are related to criteria. They can only evolve standards after they have gone through the thought process, hopefully, enabling standards to be set. In this sense, one sees a direct relationship of criteria to ambient air quality standards.

In the case of California, the standards setting forth sulfur dioxide are less stringent than the Federal standards—excuse me; criteria. I hasten to correct myself.

Senator MUSKIE. What you are saying is that the criteria implicit in California are less stringent than the Federal criteria?

Dr. MIDDLETON. I think that straightens it out.

The fact that California has less stringent numbers is probably due to the fact that the information was gained several years ago and not all the information made available through our sulfur oxides search was then available to California.

Dr. Blomquist's report to you was unavailable to them at that time. The standards in New York are almost identical to the numbers selected by the National Center for Air Pollution Control published by the Secretary. These were generated more or less within the same time span and presumably much the same information was used by each party.

Senator MUSKIE. Well, I think that about covers the questions I had in mind at this point.

Senator Boggs, do you have questions?

Senator BOGGS. Mr. Chairman, you have done very well, I think.

I have many questions myself at this time of Dr. Blomquist but Senator Baker, who was here and wanted to ask some questions and had an appointment, asked me to undertake to ask one or two of them for him.

First, what are the lowest concentrations of SO_2 in the air which may be reliably measured on a first single sample short-term basis; (2) continuous air sampling; and (3) long-term sampling annual basis?

Can you comment on that question?

Dr. LUDWIG. Yes. The sensitivity of the sampling analytical procedures selected depends on the particular need, of course. We can measure down to less than a part per hundred million and the ambient air quality criteria for SO_2 is set at for a yearly average of .015 part per million.

This yearly average of .015 is the average of many, many measurements, for instance, in our continuous air monitoring program where we take a reading every 5 minutes. These individual readings vary from .01 up to more than .70 part per million, so that the long-term average for the year is made up of the average of all these 5-minute measurements.

Now, in the National Air Sampling Network we take 24-hour samples, using a wet chemical method; these samples are brought back to the laboratory and measured. Here you have an integrated sample, averaged over 24 hours during the sampling.

Senator BOGGS. Thank you.

Now, I think we have discussed here in the questions the chairman has asked how you translate criteria into standards generally, but in New York the standards are set by an ordinance of the city of New York; is that right?

Dr. BLOMQUIST. The State.

Senator BOGGS. State samples; right.

Now, you generally, according to your testimony, have adopted the criteria published on SO_2, for example, by the Federal Government and transmitted them into standards.

Dr. BLOMQUIST. Well, in actual events, are you speaking of the State?

Senator BOGGS. Yes.

Dr. BLOMQUIST. And our air quality criteria?

Senator BOGGS. Yes.

Dr. BLOMQUIST. I am not sure that the——

Mr. WILLIAMS. No. Their State standards were developed before our criteria were published.

Senator BOGGS. Before. I see.

Here is another one of Senator Baker's questions.

If you were given the authority as written in S. 780 to set standards for certain industries, how would you proceed? How soon would such standards be promulgated?

For example, how many would you be prepared to promulgate within a reasonable time?

Dr. BLOMQUIST. Our plan includes a list of the most likely industries which emit pollutants for which criteria have been developed. We would like to have criteria available before the emission standards are developed.

I would be glad to list them for you or give you samples.

We were thinking of the steel mills, the large steam electric generating stations, the smelters, the petroleum refineries, cement plants, sulfuric acid plants, steel foundries, the alloy plants putting out largely particulate matter, the pulpmills and hydrochloric acid plants.

These would be the kinds of industries we have been thinking about. We would develop emission standards for them.

Obviously, there would have to be additional ones. We have a list of another group of the most likely industries that would be regulated. Would you like me to read them?

Senator MUSKIE. As you identify an industry, could you also mention the pollutants involved?

Dr. BLOMQUIST. Yes; I will be glad to.

In case of the steel mill, for instance, we think of the pollutants being principally particulate matter; smoke; and carbon monoxide, at least from the blast furnace.

From the steam electric generating stations, we again think of particulate matters; smoke, the sulfur oxides and for some of the new plants some nitrogen oxides would be a problem.

For the nonferrous smelters, the particulate matter and sulfur compounds. Then, referring to the specific smelters, there may be specific metallic particulate that we would have to consider.

For the petroleum refineries, again it is the sulfur compounds, hydrocarbons, smoke, particulate matter, and some odorous matter.

For cement plants, particulate matter and sulfuric acid.

For iron and steel foundries, smoke, particulate, and odorous materials.

For pulpmills, sulfur compounds, odorous matter, and for some of them, the problem of chlorine.

Senator BOGGS. Particulate matters are easier to cope with than odorous matters?

Dr. BLOMQUIST. Yes.

Senator MUSKIE. Would the Senator yield at this point?

When you speak of an emission standard, would the standard for a given industry involve more than one of the pollutants that you have

given? Would it apply to all of those pollutants at a given time or would these be standards dealing with particular kinds of pollutants and particular types of industry?

For the steel industry, you might have a national emission standard as it relates to carbon monoxide at one time and subsequently another standard applying to the steel industry dealing with another pollutant. Is that the way it would operate, in your judgment?

Mr. WILLIAMS. Yes.

Senator BOGGS. On that point, you would have to get out the criteria in the first place.

Mr. WILLIAMS. Yes.

Senator BOGGS. Before you could approach emission standards on a particular pollutant.

Mr. WILLIAMS. Yes.

Senator BOGGS. There is quite a time lag.

Mr. WILLIAMS. I believe, Senator Boggs, that the length of time it took to get out the first criteria has left the impression that it will take a long, long time to get the others out.

Senator BOGGS. Yes.

Mr. WILLIAMS. We do not believe that this first experience is indicative of how long it will take us to get criteria out subsequently.

Senator BOGGS. You are geared up now?

Mr. WILLIAMS. Yes.

Senator BOGGS. Once you get out criteria for a particular pollutant, do you construe that as a permanent criteria or a temporary criteria?

Dr. BLOMQUIST. I think we will have to consider all of these things as subject to change. Like any regulation, there would be a degree of stability certainly but as we have indicated in all of our publications, there will have to be a system developed whereby criteria are reviewed and additional information incorporated.

Senator BOGGS. The same would apply to standards.

Dr. BLOMQUIST. I think all of them have to be considered subject to change on the basis of new, additional information.

Senator BOGGS. I think that is all the questions I have at this time, Mr. Chairman.

Thank you.

Senator MUSKIE. Let me ask you this one question. It is something that Senator Boggs has stated.

Now, you mentioned sulfur dioxide with respect to more than one of the industries which you listed. You also issued the sulfur dioxide criteria.

If sulfur dioxide is harmful to health in so many industries, why attack the problem industry by industry? Why not just have a national standard governing the emission of sulfur dioxides into the air anywhere in the United States from any source?

Mr. WILLIAMS. Because the methods of controlling sulfur dioxides would vary greatly, as would the conditions under which they are released from industry to industry. I think the question that has fallen to the background often is the status of technology. When you speak about a standard, for example, an ambient air standard, I think that

we fail to realize that most of our communities would be in violation the minute after it is established, because for many sources of pollution we could not at this time meet the desirable ambient air levels, no matter how much we should like to.

Senator MUSKIE. With respect to sulfur dioxide there are only two methods of controlling flue gases or reduction in the fuel.

Mr. WILLIAMS. Yes. We are doing what we can and greatly increasing our efforts to improve that technology, which I think Dr. Middleton might want to comment on.

For example, it is not likely that the control of sulfur oxides would be one of the first emission standards areas that we would attempt to cover. We have to be concerned about what can be controlled now with available technology.

Senator MUSKIE. So that a national industry which might otherwise be subject to national emission standards might not be subject to standards dealing with sulfur dioxides even though it was an industry problem.

Mr. WILLIAMS. That is right.

Senator MUSKIE. Senator Spong.

Senator SPONG. I only have one question, Mr. Chairman, I think that the subject has been pretty well covered.

You speak of 16 cities in which commuter exposure studies are being made and will be available in July of this year. Are these 16 standard metropolitan areas rather than cities?

Dr. LUDWIG. Yes.

Senator SPONG. I assumed that that was true.

I would like a list of those 16 cities for the record. Is the Washington metropolitan area one of the 16?

Dr. LUDWIG. Yes; I believe it is.

Senator SPONG. Thank you.

(Subsequently Dr. Ludwig submitted the following information:)

The National Center for Air Pollution Control has made measurements of commuters' exposure to carbon monoxide in 14 cities: Atlanta, Baltimore, Chicago, Cincinnati, Denver, Detroit, Houston, Los Angeles, Louisville, Minneapolis-St. Paul, New York City, Phoenix, St. Louis, and Washington, D.C. Measurements will be made in Philadelphia in June 1967.

In all of the cities, measurements are made within the vehicle by sampling air from the immediate vicinity of the driver's face. Expressway, arterial, and center-city routes are used as being generally representative of road systems traversed by commuters and/or people such as taxicab drivers and patrolcar policemen. Attached are a table showing the concentrations obtained in cities for which initial data have been evaluated and a graph showing the range of exposures by road type. Generally, the higher exposures are experienced on center-city routes and lowest exposure on expressways, with the arterial routes being intermediate. Approximately 10 percent of the individual runs (averaging about ½ hour) for the center-city routes are in the range of 40 ppm to 60 ppm in most cities.

During FY 1968, the data resulting from the study will be intensively analyzed with respect to concentration of vehicles, types of roads, and profile of surrounding land, to enable us to dissect out the influence of various parameters on the commuter's exposure to CO. Such information will then be utilized in projecting commuter exposure 20 years hence, as based on traffic projections, and various schemes for the control of CO from motor vehicles.

AQ & ED Branch, NASN Section, Commuter Exposure to Carbon Monoxide

Continuous "in-traffic" measurements with trailer unit

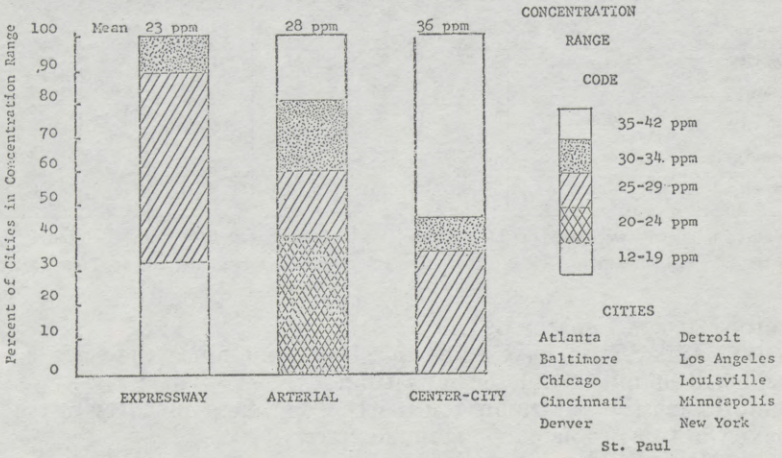
City:	*Period*
Cincinnati	Feb. 24–25, 1966
Louisville	Mar. 1–4, 1966
Atlanta	Mar. 11–17, 1966
Baltimore	Apr. 8–15, 1966
New York	Apr. 21–May 5, 1966
Chicago	May 25–June 8, 1966
Detroit	June 13–July 14, 1966
Cincinnati	Aug. 2, 16, 17, 1966
Minneapolis-St. Paul	Aug. 29–Sept. 9, 1966
Denver	Sept. 19–30, 1966
Los Angeles	Oct. 12–Nov. 3, 1966
Phoenix	Nov. 9–18, 1966
Houston	Dec. 5, 1966–Jan. 20, 1967
St. Louis	Feb. 6–17, 1967
Chicago	Feb. 27–Mar. 17, 1967
Washington	Apr. 5–27, 1967
New York City	May 1–30, 1967
Philadelphia	June 1967

"In-traffic" bag sampling (15 to 20 minutes)

City:	
Chicago	June 1965–July 1965
Cincinnati	June 1965–September 1965
Denver	October–December 1965
Philadelphia	August 1965–September 1966
St. Louis	July 1965–September 1965
Washington	July 1965–September 1966

Air Quality & Emissions Data Branch
National Center for Air Pollution Control
November 30, 1966

COMMUTER CARBON MONOXIDE EXPOSURE
BY ROAD TYPE



In-traffic carbon monoxide exposures

[Concentrations in parts per million]

City and route	Exposure during half-hour run			Short-term peak exposure		
	Minimum run exposure	Average run exposure	Maximum run exposure	Minimum peak	Average peak	Maximum peak
Atlanta:						
Expressway	16	27	39	54	77	96
Arterial	25	34	44	41	66	95
Center city	17	25	31	37	53	79
Baltimore:						
Expressway	6	13	25	10	36	83
Arterial	10	21	37	18	41	86
Center city	19	28	42	32	58	96
Chicago: [1]						
Expressway	3(13)	20(24)	35(37)	7(24)	43(52)	86(91)
Arterial	1(7)	16(16)	41(31)	3(17)	32(32)	68(59)
Center city	19(24)	34(32)	53(55)	45(36)	70(58)	109(91)
Cincinnati:						
Expressway	7	14	19	12	26	36
Arterial	7	21	36	10	40	83
Center city	21	33	54	34	60	100
Denver:						
Expressway	10	22	38	20	40	71
Arterial	16	32	61	35	65	138
Center city	21	34	54	36	69	96
Detroit:						
Expressway	11	25	54	22	51	116
Arterial	14	26	41	34	54	91
Center city	15	25	36	33	51	85
Houston:						
Expressway	2	16	39	9	29	74
Arterial	5	15	33	13	36	82
Center city	16	38	70	32	75	98
Los Angeles:						
Expressway	9	29	62	23	52	102
Arterial	24	38	60	45	74	147
Center city	27	40	60	44	68	111
Louisville:						
Expressway	6	12	25	10	21	34
Arterial	8	20	35	12	36	65
Center city	20	27	37	32	44	66
Minneapolis-St. Paul:						
Expressway						
Arterial	10	23	41	18	52	130
Center city	20	32	65	28	54	91
New York:						
Expressway	12	27	49	19	51	95
Arterial	18	34	53	25	57	95
Center city	23	40	62	41	70	95
Phoenix:						
Expressway	12	23	50	18	40	83
Arterial	13	27	43	26	56	87
Center city	27	38	54	44	72	105
St. Louis:						
Expressway	2	10	22	7	22	57
Arterial	8	17	34	17	36	70
Center city	15	28	50	28	56	109
Washington:						
Expressway	2	12	33	5	27	76
Arterial	10	20	30	22	40	86
Center city	8	26	63	13	45	116

[1] 2 separate sampling trips were made to Chicago; these data are listed separately for comparison purposes.

Note.—Data from a 2d trip to New York are not yet processed; a sampling trip to Philadelphia scheduled.

Senator MUSKIE. Senator Bayh.

Senator BAYH. I do have some questions, but since they are extensive, I will submit them later in writing.

I compliment the chairman for his thoroughness in covering the complexity of this problem in varying degrees.

Senator MUSKIE. Thank you, Senator.

Now we have Dr. Ludwig next. I think it is about time that we got to his statement.

Dr. MIDDLETON. He is Associate Director for Control Technology Research and Development, National Center for Air Pollution Control, and an excellent engineer, responsible for conducting all physical science and engineering research in our Cincinnati facilities.

Senator MUSKIE. I am sure we have a lot of questions dealing with technology so why don't we have your statement now, Dr. Ludwig.

Dr. LUDWIG. Thank you, Mr. Chairman.

STATEMENT OF DR. JOHN H. LUDWIG, ASSOCIATE DIRECTOR FOR CONTROL TECHNOLOGY DEVELOPMENT PROGRAM, NATIONAL CENTER FOR AIR POLLUTION CONTROL, PUBLIC HEALTH SERVICE

Dr. LUDWIG. Mr. Chairman and members of the committee, I am pleased to have an opportunity to participate in these hearings.

My remarks will be specifically directed toward the efforts that have been and are being made by the Department of Health, Education, and Welfare to develop technology for controlling air pollution.

The statement has been made many times that the problem of air pollution is growing faster than the development of our control technology and its application. The Clean Air Act of 1963 provided mechanisms for inaugurating steps toward accomplishing both of these goals.

Under the authority of this act, modest programs for the development of technology for several of the Nation's most critical problems have been initiated—those concerned with the control of emissions from the combustion of fossil fuels and motor vehicles.

On April 21, 1967, the President directed Secretary Gardner to inform the Congress that additional supplemental funds in 1967 will be devoted to research on controlling sulfur pollution and that substantial additional funds would be requested in 1968 and future years. Such funds would be addressed, not only to increased research and development on control methods, but also to the consideration of economic incentives for pollution control and the determination of the effects of control on industry and trade, both foreign and domestic.

The proposed Air Quality Act of 1967, with its provisions for increased resources and greater flexibility in operational procedures, would enable us to strengthen and accelerate our research and development activities and expand them into new areas, as well.

I would like to address myself to the problem which the proposed new legislation is, in part, intended to resolve—the problem of bringing to bear all of the Nation's resources, public and private—on the development of new and improved and more economical means of controlling pollution, principally by means of reducing emissions at the source.

Under the Air Quality Act, we would, I believe, be able to marshal, to a far greater extent than we have been able to do to date, the abilities of private industry, private research institutes, and universities to supplement activities on control technology development underway at Federal research facilities.

First, I would like to review research and development in control technology being accomplished under the Clean Air Act and the impact which additional resources and the broadened operational flexibility suggested by the Air Quality Act of 1967 could provide.

Sulfur oxides: The members of this committee have been aware for many years of the seriousness of sulfur oxides pollution and the limitations of measures now available to us to stem the further rise and bring about reductions in ambient concentrations of these pollutants.

Such techniques as locating new powerplants outside of urban areas, the use of tall stacks to secure better dispersion of pollutants, the substitution of low sulfur fuels or the switch to nuclear fuels are now being applied in a number of localities. The method of choice is essentially an economic one.

However, we recognize, in the face of increased demands for electrical energy, which is now doubling nationwide every 7 to 10 years, that there is need for a variety of proven methods in addition to those enumerated above which will provide for greater flexibility in location of plant and choice of fuel—methods which will provide for control of pollution at the least cost to the Nation.

As we in the control technology area view the problem, the economics of sulfur oxides control, on a systems engineering basis, is as diverse as the geographic distribution of our coal and petroleum resources, the physical and chemical characteristics of these fuels, the location of power production facilities with respect to these fuel resources and the markets they serve, and the location of power facilities to potential users of recovered sulfur byproducts. This latter factor—sale of sulfur byproducts—is an important key to the economics of sulfur control, and one which will dictate directly the price we will pay for sulfur control for large new power facilities.

The overall result of these diverse factors is the need to develop a variety of control processes ranging from "switching-to-gas" in the case of the small commercial user, such as an apartment house, to the development of new power system concepts wherein desulfurization is an integral part of the system rather than an "add-on" appurtenance.

Our research and development program to date has focused on several control systems selected on the basis of either their relatively advanced state of technological development or promise, economic considerations, or their applicability to existing as well as new powerplants.

These are (1) the alkaline injection process; (2) the alkalized alumina process; (3) the molten carbonate process; and (4) the pyrite-coal process.

This year, we have allocated about $6 million for sulfur oxides control work, about $5.5 million of which is in contract work with private organizations or other governmental agencies. Our goal this year is to develop needed information to bring all of these processes to the stage where contracts for the design, construction, and operation of pilot plants can be let on two and possibly three of these processes by the end of fiscal year 1968.

At the present time, we are discussing full-scale demonstration studies to begin this fiscal year on the alkaline injection process, a method which shows great promise not only due to its technical feasi-

bility but because it is a process applicable to existing as well as new plants.

We have also advertised for bids on a conceptual design study starting this fiscal year of a semiworks plant utilizing the alkalized alumina process—the first step in design, construction, and operation of such a plant. This contract will be awarded to a process control engineering company with broad experience in this field.

I needn't detail further our program in this area this year, except to remark that additional resources would make possible the development of stack process control methods at an accelerated rate, and would allow at an earlier date the simultaneous semiworks plant testing of a number of processes.

More resources, as indicated by the President in his memorandum of April 21, 1967, would allow us to investigate, on a deliberate and systematic basis, a broad spectrum of solutions to the sulfur problem. Exploration of new systems for flue gas treatment could be made concurrently with support for promising methods which already have been proposed to us but which we have not been able to fund.

We could also support, hopefully jointly with the industries concerned, studies on improved or more economical processes for both coal and residual oil desulfurization, studies on the control of sulfur pollution sources other than fuel combustion such as smelters and pulp manufacturers, and the development of advanced power systems incorporating sulfur recovery as an integral part of the system.

A series of systems engineering studies to define the economic impact of sulfur control on the Nation's economy are needed. Included in these systems analyses are (1) case studies in major metropolitan areas to delineate economic trade-offs and establish the relationship between schemes for future energy generation and sulfur control; (2) economics of byproduct recovery; and (3) studies to better define the sulfur problem, that is, plume dispersion, relative contribution of high and low stacks, et cetera.

In the expansion of our sulfur control program during the past year, we have relied heavily on the resources of private industry and private research institutes. We have found this procedure to be highly satisfactory. It is both technically sound and responsive to the urgency to get the work done; as our program expands, we intend to utilize contracting more and more to supplement the expertise available throughout all Federal agencies concerned with the sulfur problem.

MOTOR VEHICLES

There is little I can add to your present knowledge of the seriousness of the motor vehicle pollution problem, and of the complexities involved in the control of vehicle emissions.

Since the automobile manufacturers must custom design emission control devices to meet the diverse requirements of the many engine-transmission-weight models produced, we feel the role of the Federal program in the development of control technology for vehicle emission control is to prove out the feasibility of control concepts, which may then be followed up by hardware development by industry to fit their unique needs.

Adjuncts to control standards are the establishment of current emission levels, the development of standard test procedures, and the testing of control systems to establish their effectiveness. For the most part to date the Federal program has been concerned wih these latter activities leading toward improved testing procedures for 1970 model year cars, trucks, and buses.

This year we are undertaking several programs in the control development area. Under development by contract to Esso Research is the optimization of a system for NO_x control. This system involves exhaust gas recirculation regulated by intake manifold vacuum and thus provides superior control of the quantities of exhaust recirculated over the full range of engine speeds and load than do systems controlled by throttle position.

This year we are having developed for us by Gourdine Systems, Inc., two prototype devices for the control of particulate emissions from vehicles, one for a passenger vehicle and one for a diesel vehicle. These are electrostatic precipitators based on the principle of charging by electrogas dynamics.

We believe that the control of particulate from vehicles will eventually be needed in some areas; surely it would be efficaceous as far as control of metal additives are concerned. We have invited the petroleum and associated industries to become interested in research in this area in line with their interest in vehicular fuels and fuel additives.

Diesel smoke and odors have long been recognized for their obnoxious character. When the question of Federal standards for control of these emissions appeared likely several years ago, we inaugurated a program to define the problem quantitatively and to evaluate the efficacy of various techniques for their control.

Our first need was to develop reproducible methods for evaluation of smoke and odor and to develop standard test methods. A good deal of the confusion which exists today over the evaluation of smoke and odor from diesels stems from this lack of standard evaluation techniques.

To implement this program, we utilized the services of private contractors and consultants as well as those provided by Federal facilities. We have developed new procedures for evaluating smoke utilizing an optical system developed in our laboratories and for odors utilizing chemical odor standards, These odor procedures for the first time should allow some degree of standardization to be obtained.

We plan to utilize these procedures to evaluate the effectiveness of control methods for smoke and odor control such as catalytic mufflers, fuel injection modifications, engine derating, fuel additives, exhaust dilution, maintenance, fuel quality, and electrostatic precipitation.

In the coming fiscal year, we will continue work on systems for control of nitrogen oxides, diesel odor and smoke, and particulates. We hope to greatly expand work on methods for attaining significantly better control of hydrocarbon and carbon monoxide emissions, either along the line of improved engine modifications or by exhaust treatment methods such as afterburners or catalytic converters.

In consideration of the costs to the Nation for vehicle emission control, we feel that a systematic approach to all methods proposed for

control should be explored in depth, starting with systems engineering studies of cost-efficiency relationships for the various control systems presently suggested, for example, noncatalytic afterburners that show promise for attaining significantly greater reductions than those presently attainable, improved catalytic converter systems, or induction system changes of a major magnitude in comparison to those now utilized.

The costs and benefits of all of these systems should be evaluated in relation to our continuing need for higher and higher degrees of control, and should encompass the gamut of variables involved, including the role of fuels and fuel additives as well as the vehicle powerplant. Here again economic tradeoffs will be involved.

A subject that will be probed in depth during the coming year concerns the time requirements for essentially pollution-free vehicles.

The problem in this regard stems from the number and complexity of the factors which are needed as input for such determination. Projections to date indicate that total emissions will reach their minimum levels about 1980.

However, such projections based on total emissions alone ignore a number of important factors. Essential is knowledge of future physical parameters of an urban area such as its geographical extension and its industrial, commercial, and residential configurations, future traffic patterns dictated by such growth, and the ameliorating effects of improved urban transportation systems.

Another factor concerns the various effects of vehicular emissions as these are quite different for the various pollutants, for example, carbon monoxide toxicity, the irritating and toxic properties of photochemical smog or its plant damaging or visibility impairing and discoloration properties, and toxic effects of particulate matter, especially the residues from fuel additives. To further complicate the matter, one must consider a number of parameters dealing with effects, for example, for eye irritation, both severity of irritation and the total "person-hours" of exposure above the eye irritation threshold.

Projections which have been made to date have not clearly delineated the respective roles of all of these parameters. We believe the problem is amenable to clearer definition, and intend to undertake comprehensive systems engineering analyses in a number of major metropolitan areas. From these analyses should emerge a clearer understanding of both the ameliorating effects of presently attainable controls and the degree of control eventually needed and the timing required.

As a preliminary to the possibility of undertaking research and development in the area of propulsion systems that would be essentially pollution free, we have awarded two contracts to explore the most feasible approaches in both advanced mechanical designs and electrochemical systems.

On April 6–8, 1967, the National Center for Air Pollution Control, jointly with Columbia University and Brooklyn Polytechnic Institute, sponsored a symposium on "Power Sources for Electric Vehicles" that brought together about 250 experts to discuss the technical problems involved in producing an acceptable electric powered vehicle.

CHEMISTRY AND PHYSICS OF AIR POLLUTANTS

An important activity which is necessary to assess the need for control technology development is the chemistry and physics of air pollutants. Research and development in these areas provide the tools for defining the problems and evaluating control progress.

Extended programs in these areas are needed to further clarify controversial issues and point up emerging problems. Included in needed investigations are further studies in a number of areas, for example, reactions which take place in the atmosphere after pollutants are emitted, the relative roles of the various precursor pollutants which result in photochemical smog, the increasing incidence of photochemical smog in eastern cities, and a better definition of the toxic components of particulate in the ambient atmosphere, and their interactions with gaseous pollutants to produce possible potentiating effects.

The development of standard methods for measurement of air pollutants and their acceptance and application nationally is another area of urgent need. We are undertaking in Federal laboratories and are supporting by grant a host of studies in these areas. Increasing resources over the years have allowed us to make an impact on defining these problems. However, such research is quite complex and much yet still remains to be done.

EFFECTIVENESS AND COST OF CONTROL EQUIPMENT

As discussed previously, the major share of our effort for control of emissions from stationary sources has been focused on the sulfur oxides problem. In addition, however, we have undertaken work on the application of industrial bag filtration on evaluation of fuel additives, and on the control of incinerator emissions.

We have just begun basic studies on a pilot-model trench incinerator, and are supporting demonstration grants by the cities of Chicago and New York. The former will consist of full-scale long-term tests of three control devices for apartment house incinerators. The latter will test a number of control methods at one of the incinerators operated by New York City.

An area which has not been adequately promoted to date is assistance to industry in improving the effectiveness and reducing the cost of control equipment and applying known technology to new situations. We envision several areas wherein the Federal Government could be particularly effective, as follows:

1. Joint support and direction with control equipment manufacturers to investigate shortcomings in present equipment and to develop solutions which would be available to all manufacturers. Federal sponsorship of such programs would be an effective catalyst in bringing competitive groups together to study common problems. The plan has the added advantage of keeping such research "topical," provides the sharing of the direction of efforts by those who know the problems best, and would insure rapid commercial availability of new developments.

Joint efforts of this type could be carried on with many trade associations including the various Division of the Industrial Gas Cleaning Institute, for example, in the areas of electrostatic precipitators, mechanical collectors, fabric collectors and wet collectors. This organization represents the major manufacturers of control equipment in the United States.

2. Joint support and direction of research and development with trade associations with unsolved air pollution problems. Here again the close association between Federal participants and industry representatives would be most fruitful for keeping research efforts "on track." Problems which came to mind in this regard are those connected with the pulp industry, the rendering industry, foundries, secondary materials reclamation and incineration to name but a few.

INDUSTRIAL EMISSION STANDARDS

The provision in S. 780 proposing Federal regulations for control of emissions from major industries requires that appropriate consideration be given to technological and economic feasibility. The Director of the National Center for Air Pollution Control has suggested a tentative list of industries to be subject to Federal regulations as follows: Metals, power, coking, petroleum, pulp and paper, cement and lime, acid, phosphate fertilizer, glass, and chemicals.

Included in this diverse group are industries of varying size and with effluents containing the entire spectrum of pollutants; particulates, gases and vapors, and odorous materials.

Although it is too early to define all of the individual problems based on lack of adequate control technology to meet future ambient air criteria, it may be presumed that the application of Federal standards will bring into focus many deficiencies in our ability to adequately control emissions at a reasonable cost. Many of these we are aware of at the present time.

The Federal role in the development of acceptable control technology to meet these needs could proceed along three lines: (1) Support to industry to conduct research and development of control techniques in its own facilities; (2) joint support and direction of research and development as previously discussed; and (3) research and development carried out by the Federal Government in its facilities or by contract.

The method of choice would depend on the size of the industry involved and its capabilities to share support or carry out the required investigations.

S. 780 provides for "Federal payments to public or private agencies, institutions, or persons or part or all of the cost of acquiring, constructing, or otherwise securing devices, methods, or other means of preventing or controlling discharges into the air of various types of pollutants."

This broad provision will be effective in providing support to industry directly, particularly in the construction and testing of new control processes to demonstrate their feasibility. The production of realistic pollutant streams throughout a range of operating condi-

tions is an important feature of proving out a new technique—one which industry itself is best able to provide.

METEOROLOGICAL CONTROL

The use of our air resource to the maximum extent possible without exceeding ambient air quality criteria has been proposed as a significant means to control pollution. The use of tall stacks and the construction of new powerplants outside our urban complexes are specific examples of this approach.

We agree that this means should be employed, particularly as an interim measure pending the development of additional control technology. As a result, we have developed cooperatively with the Environmental Sciences Services Administration of the Department of Commerce a substantial group of professional meteorologists in the National Center for Air Pollution Control who are refining our capabilities in several areas:

(1) Extending our air pollution potential advisories to a 12- to 24-hour forecast basis, quantifying these, and reducing the geographic scale for which these advisories are applicable;

(2) Improving our mathematical models for dispersion and transport of pollutants including better understanding of source-receptor relationships; and

(3) Completing an air pollution climatological atlas for the entire contiguous United States.

All of these activities are pointed toward optimum utilization of our air resources. In direct concern for sulfur oxide emissions from tall powerplant stacks, we are mounting a field study in Pennsylvania, where three large mine-mouth powerplants are now under construction or in the planning stage, to further define the efficacy of this method of control.

A full report on control technology research and development activities and on future needs would take a great amount of time.

Mr. Chairman, very briefly, we are pursuing and will continue to extend our research into many areas as resources allocated to this activity increase. Although it is difficult to determine the amount of control technology research being conducted by various industries, we have noted a substantial increase over the past year. The Air Quality Act of 1947, by providing additional support for such research and development and allowing Federal support to industry directly, would be beneficial in accelerating the development of tools to attain cleaner air.

I would be happy to answer any questions.

Senator MUSKIE. Dr. Ludwig, with respect to national emission standards, with respect to what industries and what pollutants is technology now available to support the proclamation of national emission standards?

Dr. LUDWIG. The first one which comes to mind would be in the particulate control area. Methods for controlling particulates have been known for a number of years, and the degree of control selected is

related to the economic burden for such control. This is one area that could be included in such emission standards.

Senator MUSKIE. What industries and what time period can you identify now in that connection?

Dr. LUDWIG. The general timetable or the industries that you would select would be those for which control of particulates is economically justified; for instance, in the steel industry, in the cement industry, in pulp industry for control of particulates. There are methods available to control these emissions.

Senator MUSKIE. Does the technology and the economics today justify the proclamation of emission standards for particulates dealing with those industries almost immediately after the enactment of S. 780 into law?

Dr. LUDWIG. As Dr. Middleton has mentioned, the promulgation of such standards would follow the publication of air quality criteria for such emissions. This is the first step.

I think the second step is for many industries——

Senator MUSKIE. Well, with respect to particulates, do you need anything more than you now have? For instance, let's get down to a particular industry, the steel industry. The steel industry is now being controlled as to particulates in the Los Angeles area, for example, and in other areas. So you have the technology.

Dr. LUDWIG. Presumably in terms of economics it is reasonable enough at least to be used in the Los Angeles area and other areas.

Senator MUSKIE. Now what is it that would prevent your establishing national emission standards for the steel industry dealing with particulates almost immediately after the passage of the law?

Dr. LUDWIG. This could be done.

Senator MUSKIE. You see no obstacle to it?

Dr. LUDWIG. No, sir.

There are other areas, for instance, in small foundries, where there are not economical methods available at the present time. This is one of the areas that hopefully some R. & D. could be done to develop adequate methods.

Senator MUSKIE. Now are there other specific pollutants for which technology within the limits of reasonable economics is now available on an industry basis?

Dr. LUDWIG. Yes. For example, just to name one here, the control of carbon monoxide in petroleum refineries by burning these emissions or the control of polynuclear hydrocarbons from catalytic cracker generators can be done by known technology. The control of sulfur emissions in refineries by recovering sulfur can be carried out.

The control of sulfur emissions from smelters, a process which is utilized in some cases today to the extent of the need to recover sulfur products, is being carried out today—operations of this sort.

Senator MUSKIE. Could you supply as complete data as is available to you on this point for the record?

Dr. LUDWIG. Yes.

(Subsequently, Dr. Ludwig submitted the following material:)

77-515 O—67—pt. 4——4

Status of current technology in the control of emissions to the atmosphere

[C—Control technology generally available; NC—Control technology not generally available; CO—Carbon monoxide; HC—Hydrocarbons; SO_x—Sulfur oxides; NO_x—Nitrogen oxides]

Source	Particulates		Sulfur oxides		Carbon monoxide		Others		Remarks
	C	NC	C	NC	C	NC	C	NC	
Domestic and commercial heating plants:									
Coal fires (not hand fired)		(a)	X			X	Smoke	NO_x	CO not of major concern.
Oil fired		(a)	X			X	do	NO_x	Control of SO_x only by switching to low sulfur fuel.
Gas fired					X			NO_x	Control of CO by good combustion.
Industrial heating plants:									
Coal fired	X			X	X		Smoke	NO_x	Control of particulate during soot blowing needed.
Oil fired		(a)		X	X		do	NO_x	Partial control of NO_x is possible.
Gas fired					X			NO_x	Do.
Electric generating plants:									
Coal fired	X			X	X		do	NO_x	Control of particulate during soot blowing needed.
Oil fired	X			X	X		do	NO_x	Partial control of NO_x is possible.
Gas fired					X			NO_x	Do.
Hand-fired coal burning furnaces	X				X		Smoke	NO_x	Controlled by elimination of hand firing of coal which may be a hardship on low-income households.
Incinerators:									
Domestic; commercial; industrial:									
Single chamber		X				X		Smoke; organics	Can be controlled by eliminating single-chamber incinerators.
Multiple chamber	X				X		Smoke; organics		More effective control of particulate emissions is needed.
Municipal	X				X		do		
Auto body and scrap wire	X				X		do		
Mineral industry:									
Cement	X							NO_x	Particulate control difficult for old plant.
Insulation	X							NO_x; odors uncontrolled in some glass wool plants.	

Glass manufacturing	X						Fluorides	NO_x	Can control fluoride and visible emissions by raw material control.
Frit	X							NO_x	
Phosphate fertilizer	X						Fluorides; ammonia		Fluoride control difficult on older plants and certain processes.
Asphalt concrete batching	X							Odors; NO_x	Fugitive dust control difficult at older plants.
Concrete batching	X								
Carbon black:									
Furnace black	X							NO_x	SO_x may be a problem and cannot be controlled.
Channel black		X						NO_x	
Coal cleaning	X								Older plants often difficult to control.
Charcoal manufacturing	(a)							Organics; smoke	
Ceramics	X							Fluorides; NO_x	Fluorides from decomposition of certain clays.
Refractories	X							NO_x; fluorides, if in raw material.	
Rock and gravel processing	X								Fugitive dust difficult to control.
Metallurgical industry:									
Iron and steel:									
Coke plants:									
Slot type		X		X			NH_3, benzol, toluol, organics.	Odors	Emissions from charging and discharging ovens. Old plants are very difficult to control.
Beehive		X		X				Organics; odors	Completely noncontrolled.
Blast furnace	X				X			NO_x	CO used as fuel.
Sintering plants	X			X			Fluorides	NO_x	Control difficult on older plants.
Open hearths	X						do	NO_x	Being phased out.
Oxygen lance open hearths	X							NO_x	
Basic oxygen	X				X			NO_x	Replacing basic open hearth.
Electric furnaces	X							NO_x	Emissions not controlled during tilting and charging.
Scarfing	(a)							NO_x	
Grey iron cupola:									
Production	X				X		Organics	NO_x	
Jobbing	(a)				X		do	NO_x	
Ferroalloys	X							NO_x	
Aluminum:									
Reduction	X						Fluoride	Carbonaceous matter	Fluoride control poor in Soderberg furnaces.
Secondary operations	X						Chlorine		
Smelting:									
Lead ores	X		X					NO_x	
Zinc ores	X		X					NO_x	
Copper ores	X		X					NO_x	
Refining:									
Zinc	X							NO_x	Particulate control at small scrap reclaiming operations is economically burdensome.
Brass	X							NO_x	
Taconite plants	X							NO_x	

See footnote at end of table, p. 2277.

Status of current technology in the control of emissions to the atmosphere—Continued

C—Control technology generally available; NC—Control technology not generally available; CO—Carbon monoxide; HC—Hydrocarbons; SO_x—Sulfur oxides; NO_x—Nitrogen oxides

Source	Particulates		Sulfur oxides		Carbon monoxide		Others		Remarks
	C	NC	C	NC	C	NC	C	NC	
Petroleum industry:									
Petroleum refining:									
Separation (crude distillation, etc.)							HC, H_2S		
Conversion:									
Catalytic cracking	X				X		H_2S	NO_x	
Reforming							H_2S		
Treating							Odors		Odors often noticeable.
Blending							HC		
Petroleum production							HC		
Petroleum marketing:									
Bulk plants							HC		
Service stations								HC	Partial control possible.
Solvent evaporation:									
Drycleaning							Solvents		Recovered.
Paint spraying	X							Solvents[a]	Generally uncontrolled.
Industrial storage								do	Breathing losses usually uncontrolled.
Degreasing							Solvents		
Bake oven							do	No_x	
								Water vapor	Water vapor controlled in Europe. Some odors detectable at <1 ppb.
Kraft pulpmills:									
Digesters							Sulfur compounds		
Smelt tank	X						do		
Lime kiln	X						do	No_x	
Recovery furnace	X			X	X			Sulfur compounds; No_x	Control of odorous sulfur compounds usually not satisfactory.
Evaporators								Sulfur compounds and odors.	
Oxidation towers							Sulfides, odors		
Chemical industry:									
Sulfuric acid			X				Sulfuric acid mist	No_x (chamber process)	Better ocntrol of SO_2 desirable.
Nitric acid							NO_x		
Hydrochloric acid							HCl, solvents		
Phosphoric acid							Fluorides; phosphoric acid mist.		Flouride control often difficult. Particulate control difficult for submerged combustion acid evaporation.
Hydrofluoric acid							HF		
Chlorine							Cl_2		Cl_2 leaks are hard to control at old plants.

Ammonia (synthetic)						NH_3 organic bases		Well-developed technology and mammoth plants.
Lime	X						NO_x	
Soda ash:								
Ammonia soda	X					NH_3		
Trona	X							
Caustic soda:								
Lime-soda								Practically obsolete (see chlorine plants).
Electrolytic	X					Cl_2		Odor from Cl_2 distillations tower bottoms, if exposed.
Polyethylene						HC		Tight process system.
Polyvinyl chloride						HCl, vinyl chloride, vinylidene chloride, vinyl acetate.		Do.
Alum	X					Mists		Old plant controls may be poor.
Paint and varnish	X					Odors, solvents	NO_x	Old plant controls difficult. Often have odors.
Synthetic rubber						HC, solvents, odors		Odor control only fair.
Rubber tire manufacturing	X						Odors	
Oil bodying operation	X					Odors		
Formaldehyde					X	Methanol, formaldehyde, HC, methanol.		Tight system.
Methanol (synthetic)					X			Do.
Phenol (synthetic)						Benzene, toluene, odors		
Rayon						Sulfides, carbon disulfide odors.		Odor control only fair.
Insecticides:								
Chlorinated	X					Cl_2; HCl	Odors	
Phosphorus type	X						do	Some are supertoxic.
Carbamates	X							Some are highly toxic. Nonpersistent.
Soap and detergent	X						do	Partial control of odor possible.
Phosgene						Cl_2 and phosgene		Highly toxic. Tight system; mainly captive use.
Phthalic anhydride	X					Odors		
Food processing and agriculture:								
Cotton ginning	X						Pesticides	Some gins have cost problems. Incineration of cotton trash of concern in regard to arsenic.
Alfalfa dehydrating	X						Odors; NO_x	Often unsatisfactory.
Feed and grain mills	X							
Flour mills	X							
Meat smoking	X					Odors; smoke		
Starch manufacturing	X							
Fish processing							Odors	Cl_2 scrubbers. Partial control of odors possible.
Coffee roasting	X					Odors	NO_x	Fume burners.
Rendering						do		Complete odor control difficult.
Agricultural burning:								
Fields		X					Organics, odors	
Forests		X					do	
Crop spraying						Drift	Many insecticides and herbicides.	Hazardous to life unless carefully done.

(a) Emission control is possible but cost is unacceptably great compared to capital investment of plant or as a factor in cost of finished products or in relationship to the ability of persons responsible for control to bear the costs.

NOTE.—Nitrogen oxides (NO_x) are always formed in high-temperature combustion. Amounts vary with conditions. Feasible means for adequate control of emissions are not available.

Senator MUSKIE. I have listed some examples here that I think would be helpful to have for the record on industries by type of pollutants that you feel need to be controlled nationally for which we now have the available technology and is within the limits of reasonable economics.

With respect to your testimony, Dr. Ludwig, your reading of the provision in S. 780 called my attention to a problem that I had not previously noted. This is section 2(A)(5) which you quoted, and I will read the part that you quoted: "Federal payments to public or private agencies, institutions or persons of part or all of the cost of acquiring, constructing, or otherwise securing devices."

Now when I first read this provision, I assumed what the bill was talking about was R. & D., but this reads as though it could be authority for Federal support for the acquisition of control equipment by industries.

Dr. LUDWIG. No, I think that this refers to the acquisition or the first installation of a particular type of control equipment in an industry. This would be used to develop the engineering data that would be needed to firmly establish the practicability of the method.

Senator MUSKIE. Develop and improve new methods.

Dr. LUDWIG. Yes.

Senator MUSKIE. Rather than already established technology.

Dr. LUDWIG. Yes.

Senator MUSKIE. And its acquisition. I thought that ought to be made clear.

I want to call to your attention the testimony last week of our two friends from Great Britain. Have you read the testimony of last week on the tall stack technology?

Dr. LUDWIG. Yes, sir; I was here.

Senator MUSKIE. Am I in error in recalling that from Mr. Clarke's point of view tall stack technology was the answer to Great Britain's air pollution problem? If that was accurate, would you respond either in response to that question or generally to his optimistic evaluation of tall stack technology as an answer.

Dr. LUDWIG. I don't think that I could disagree that tall stacks are serving a very useful purpose today. It would appear to be the only available method for alleviating the sulfur oxides problem in many congested areas pending the development of better methods. However, we don't agree technically with the conclusions reached by Mr. Stone and Mr. Clarke in their paper.

We think that there are many deficiencies. I have reviewed this paper; there are many things in the paper that still need exploration. We have been conducting a research program over the last several years cooperatively with the Tennessee Valley Authority. This last year we have supported the technique of following stack plumes to determine the ground level concentrations from these under various meteorological conditions.

We intend to continue this next year and to inaugurate quite an extensive program on large mine-mouth Pennsylvania powerplant plumes to better define the usefulness of this technique.

In addition to this we have inaugurated with industry this year by contract, supported jointly by the Public Health Service, the

Edison Electric Institute, the American Petroleum Institute, and Bituminous Coal Research, a program to determine the reactions between sulfur oxides in the plume after it is emitted. This is a 3-year, $300,000 research program.

I think the conclusions reached by Mr. Stone and Mr. Clarke are a little bit ahead of the data they have reported to support their conclusions. For instance, one of the things, to name one here, that they do not explain in their paper for this powerplant, which is some 10 to 20 miles from any other source of pollution, is where the concentrations of "background" sulfur dioxide come from. It may very well be that, under certain meteorological conditions, these "background" concentrations come from the very powerplant that they are trying to indicate is in the "clear."

Now we don't have the meteorological data; I can't say that is right or wrong. I think our point has been and continues to be that the problem needs further clarification, in particular there is a need to compare the climatology we have here in the United States with that in England.

Another point, in their paper they point out that when you have inversion conditions, this essentially keeps the pollutants from reaching the ground. However, as we can show and have shown in our climatological studies (we intend to publish in this climatological atlas), that due to the mixing which occurs for a large proportion of the days in this country, these "emissions" which are temporarily kept aloft, are brought down to the ground. We suspect that this condition, plus also the light-wind limited mixing condition, are occurring in their studies.

So, I think our position is that we are inaugurating this study in the Pennsylvania area on large powerplant stacks to further elucidate the use of tall stacks as an adequate method.

Senator MUSKIE. Now let me put this question to you. With respect to national emission standards and industries in which sulfur oxides are a problem, would you consider that tall stacks is a sufficient technological answer so that you can write national emission standards based on the availability of the tall stacks to deal with the sulfur oxides problem?

Dr. LUDWIG. I think the point here is that an emission standard should take into account the height of the stack because obviously what you get from a thousand-foot stack is better dispersion and lower surface concentrations than you are going to get, say, using a fifty-foot or a hundred-foot stack. I think there is going to have to be a tie-in between the emission standards and the height of the stack, the quantity of these emissions, and the thermal lift that we have for a particular process.

The thing that we are attempting to do in these studies is to more clearly define the total role of the stack under all types of climatological conditions rather than to base it on more limited information of what is occurring within 2 or 3 miles of the stack.

For instance, in Pennsylvania we expect to trace the plume up to 50 to 60 miles because there are indications that you can get substantial concentrations of sulfur oxides from the tall stack plume some distance removed from the stack itself.

Senator MUSKIE. As I gather your answer, it is not your judgment that the tall stack technology at the moment is a sufficient basis for a national emission standard dealing with sulfur dioxide at this point in its development.

Dr. LUDWIG. I think we are going to have to consider the height of the stack in the emission standards. The research that we would like to do pertains to further defining all of the ramifications that occur under various climatological conditions in which these plumes are mixed and brought down to the ground.

Senator MUSKIE. What I am really trying to get is some sense of the imminence of action. Mr. Stone and Mr. Clarke indicated that in their judgment the tall stack is the answer to the sulfur oxide problem—at least that was my impression of their testimony. Now if you had a similar impression of intention for the tall stack control and in your judgment this was the controlling requirement, I would expect that if the national emission standards provision were written into the law, very shortly we would expect national emission standards based on that technology.

Based upon your evaluation of the tall stacks potential is there some possibility of imminent action?

Dr. LUDWIG. Yes. We have developed a knowledge of tall stack technology, in my opinion, that goes much beyond the propositions proposed by the Stone and Clarke paper. We have considered in our tall stack technology the light wind mixing condition which they completely ignore and the fumigation condition which they mention briefly. So our present considerations, based upon some degree of experimentation and theoretical grounds, allow us to estimate ground level concentrations for different types of weather regimes.

What I am saying, in the Pennsylvania study, we would like to extend this knowledge, verify it, and sharpen it up to an even greater extent than we know today. I think we do have the technology for the tall stack evaluation procedure sufficiently developed so that we can make estimates of ground-level concentration under various meteorological conditions.

Senator MUSKIE. I still have not been able to get you to do any guessing.

Well, I have assumed up to this point that there are two possible answers or at least two areas in which the answer must be found, control of the flue gases within the stack and desulfurization of the fuel.

Now is the tall stack technology a third, as distinguished between these two?

Dr. LUDWIG. Yes.

Mr. WILLIAMS. A supplementary one.

Senator MUSKIE. But not a total?

Mr. WILLIAMS. No.

Dr. LUDWIG. I would say it may be a total one. For example, it may very well be that the technology of the tall stack in a western Pennsylvania powerplant will be sufficient so that the ground-level concentrations from this plume do not exceed the air quality standards.

Senator MUSKIE. So that that poses a particular plant in a particular location. I am posing the possibility of technology as the basis for national emission standards. Is the tall stack a potential in this connection in dealing with sulphur oxide?

Dr. LUDWIG. The tall stack versus the low stack has a place either as applied to an individual source or to a community source; however the situation is further complicated. But it could very well be that the economic tradeoffs—and this is one of the things that I tried to cover in my testimony—might be a partial desulfurization of fuel combined with tall-stack technology.

Senator MUSKIE. As part of a national standard?

Dr. LUDWIG. As part of a solution to a particular powerplant.

Senator MUSKIE. That is something different than a national standard.

Mr. WILLIAMS. If I may add something, please, a national standard would not be a standard on sulfur emissions period, but a standard based on those industries that are responsible.

Senator MUSKIE. I realize that. The steel industry has a sulfur oxide problem, does it not?

Mr. WILLIAMS. Yes.

Senator MUSKIE. I recall you so identified it.

Dr. MIDDLETON. Yes.

Senator MUSKIE. In your judgment is it possible that if this law is enacted, that we might expect a national standard dealing with steel industry emissions of sulfur oxide based solely on a tall stack technology?

Mr. WILLIAMS. It is not likely for several reasons, one of them being that it would not be technically feasible to place stacks that tall on steel mills, considering the ways in which they emit sulfur, as compared to a coal-burning powerplant which has quite a different problem in controlling sulfur and which is feasible of accomplishment, in part, by use of tall stacks.

I think, as Dr. Ludwig pointed out, we have this research underway which will give us a better idea as to what extent tall stacks on powerplants are an adequate method of controlling sulfur.

Senator MUSKIE. So there are sufficient doubts now in the Department that you do not see any immediate action if this law becomes effective to base national standards upon the tall-stack technology with respect to any particular industry?

Dr. MIDDLETON. My reluctance to give you a date, Senator Muskie, stems from the fact we have not yet validated the theoretical models.

Senator MUSKIE. I am not interested so much in the date as I am in the potential of this technology.

Dr. MIDDLETON. Its utility and whether in fact it is feasible to use for this purpose is as yet not clear cut.

Senator MUSKIE. On the basis for a national emission standard.

Dr. MIDDLETON. The potential for the tall stack as a factor in national emission standards may be real; but if there are, in fact, further atmospheric reactions because of the high stack putting this plume up beyond the immediate effect on public health, adverse effects upon atmospheric quality itself may mitigate against the use of high stacks in establishment of national emission standards. The high stack may simply remove the problem from one level, altitudinally speaking, to another.

Senator MUSKIE. That is what troubles me about it. It is obvious I am not focusing my question in the way that will resolve the prob-

lem that I am troubled with. These fellows last week said this is the answer.

Dr. MIDDLETON. We are saying this is not the answer as clearly as they said it is. We are saying there is much to be learned, and much we need to know. We are not advocating the tall stack as the sole solution to the air pollution problem today.

Senator MUSKIE. You know if it is the answer, it poses a horrible picture, a picture of a landscape populated by stacks which, if they reach high enough——

Dr. MIDDLETON. It sounds as though it is advocated by Herblock, himself.

Senator MUSKIE. We could have a big black cloud over us. That is the problem that their testimony suggests to me. I am just trying to find out if it suggests anything like that to you, or whether there is some real merit to it. Whatever doubts do you have, guessing a little bit, on the proposition that they pose, that the tall stack is a real answer in the sulfur oxide problem?

Dr. MIDDLETON. May I comment further? In those areas where sulfur is an element in short supply the last thing in the world a nation or a country would want to do is to expel its sulfur oxides up through, however high, the stack, if there is, in fact, a way of recovering the sulfur as a resource.

Senator MUSKIE. Well, we might be able to put the mining industry into orbit.

Mr. WILLIAMS. It may be that in Great Britain, sending sulfur to France is considered a solution to the problem.

Dr. LUDWIG. The Stone and Clarke study, as I see it, using ground-based sampling stations located 3 miles from a 450-foot stack, in my opinion is a very limited investigation of the total problem of ground level concentrations of pollutants that come from this tall stack.

One of the things that is not explained in their analysis is the source of the high background levels of sulfur oxide. They just say it comes from some place.

Senator MUSKIE. Well, they did suggest at one point it came from residential sources, didn't they?

Dr. LUDWIG. But the point is that if these residential sources are located 10 to 20 miles away, according to their testimony; this is the big unexplained point. The thing that they have not considered in their analysis are other meteorological conditions, the light wind mixing and the fumigation conditions, two entirely different conditions than the one they investigated here. In other words, in my opinion, they have not made a total analysis of the problem. I think they have drawn unwarranted conclusions on the basis of the data, at least what they have reported in their paper.

Senator MUSKIE. You fellows are sometimes as careful as a lawyer in citing a proposition, but I think you have made your point clear.

Would it be helpful to you if you were given an opportunity to submit for the record an analysis of that paper?

Dr. LUDWIG. Yes, we can do this.

Senator MUSKIE. Without objection, we will receive your analysis and put it in the record.

(The analysis was subsequently furnished for the record and is as follows:)

ANALYSIS OF STONE AND CLARKE PAPER PRESENTED TO SUBCOMMITTEE ON MAY 10

The following comments on the paper by Stone and Clarke concern, for the most part, the limited scope of the High Marnham sulfur dioxide survey as it pertains to a complete evaluation of the ground level concentrations of sulfur dioxide resulting from the operation of the High Marnham power station. Although considerable data are available in the paper for the 16 stations located in a ring approximately 3.5 miles from the power plant, data are not available for evaluation from other points at greater distances from the plant, nor have meteorological data been reported on which to base an interpretation of the data presented. In other words, a review of the paper by the National Center for Air Pollution Control leads us to disagree with the conclusion that the efficacy of tall stacks in dispersing pollutants from the High Marnham Power Station has been conclusively demonstrated by the limited sampling program and analysis reported, and that the results reported apply by inference to all situations. The program of the National Center for Air Pollution Control has been and will continue to attempt to objectively evaluate ground level concentrations attributable to emissions from tall stacks at all distances from the stack and to relate these to meteorological conditions. The application of various mathematical models combined with the dispersion climatology for an area will then allow a complete evaluation of the ameliorating effects of tall stacks, rather than a limited evaluation such as presented by Stone and Clarke. We are very interested in establishing, on a firm scientific basis, the role of tall stacks in reducing concentrations of pollutants at ground level, to the end that tall stacks may be fully utilized as a means for alleviating the effects of tall stack emissions. Specific comments on the Stone and Clarke paper follow.

1. In essence we find ourselves in agreement with Stone and Clarke in respect to certain stack design features: (a) We agree in principal that lower ground level concentrations will occur where steps are taken to conserve the bouyancy of the power plant plume. Conserving heat by intermingling plumes with a "multiflue" stack does add to the thermal plume rise and increases the effective height of emission; (b) we also agree that a stack gas exit velocity which is too high may in fact detract from stack performance rather than enhance it. A very high efflux velocity will result in entrainment of relatively cool ambient air into the plume thereby limiting the thermal rise which would otherwise occur.

2. We cannot agree, however, that the efficacy of the two 450-foot stacks has been clearly demonstrated. We appreciate the difficulties involved in evaluating the overall effect of a power plant by ground level measurement and the difficulties in siting measuring stations to evaluate ground level concentrations under a variety of weather conditions. Nevertheless we must point out that under most atmospheric conditions the effective plume height of the High Marnham plume is such as to cause the point of maximum ground level concentration to fall beyond the 3.5 mile circle of samplers set out in the study. Data supplied to us by the Tennessee Valley Authority for power plants of about this size demonstrate that the point of maximum ground level concentration can occur from 8 to 12 miles from the plant.

3. It should be noted that the Stone and Clarke paper attributes the highest average ground level concentrations (30–50 pphm), which occurred near the power plant, to sources from 20 to 30 miles away. One is readily lead to the question, "What were the sources of these high SO_2 concentrations 20–30 miles upwind, and what might the concentrations SO_2 20–30 miles downwind from the High Marnham plant be during the same period?" Both of these questions need definitive answers before the efficacy of the High Marnham tall stacks can be established.

It would be interesting to hear Stone's and Clarke's explanation of how a "* * * break-up of stable atmospheric conditions * * *" could persist "* * * for eight consecutive hours * * *" (p. 7). This condition might very well have been a light wind, limited mixing-layer situation with the power plant itself contributing most of the ground level pollution. (For a discussion of this condition see p. 4 of the attached report, "Potential Dispersion of Plumes and Large Power Plants.") Since only very limited meteorological data were included in the analysis, we could not evaluate this possibility. We would also like to know the details of the "* * * careful checking * * *" which reaffirmed that the plant was making no contribution to this high readings. It is questionable whether this can be done adequately without aerial tracing of the plume trajectory and dispersion.

Also, it would be interesting (although not pertinent to the High Marnham tall stack problem) to know the very high ground concentrations immediately downwind of the sources 20 to 30 miles away which allegedly contributed most of the high readings at the High Marnham Station, particularly since these background levels were attributed to low level sources, i.e., "* * * cities and industrial areas * * *"

4. Examining Table IV, we find an hourly-mean SO_2 concentration from the power plant alone of $\geqq$ 10 pphm occurred on the average of 5.4% of the time considering the group of 16 SO_2 measuring gages located in the ring surrounding the power plant. However, for most conditions only one of these stations (or possibly two) would record high readings at any one time, this being the station downwind of the stack. It can be concluded that for the periods when the wind was blowing toward a given sampler, the concentration was $\geqq$ 10 pphm about 80% of the time (the 5.4% indicated above multiplied by the number of samplers).

5. The Stone and Clarke paper, by averaging observations from stations downwind of the power plant together with observations in all other directions which could not be affected by emissions from the stack, arrives at the conclusion that the overall effect of the plant was equivalent to adding only 0.1 to 0.2 pphm to the background readings for the group of 16 stations. Of more concern to an individual downwind of the power station is the ground level concentration when the wind is blowing from the station towards him. In a less general paper on the High Marnham plant written by W. F. Gilliam, A. Martin and F. R. Barber (Reference 13, p. 12 of the Stone and Clarke paper) we find the information given below. The Gilliam paper is published in the Proceedings of the International Clean Air Congress (London 1966) and is titled, "Sulfur Dioxide Concentrations Measured Around a Modern Power Station."

(a) In discussing SO_2 measuring station number 2 at the High Marnham power plant Gilliam reports, "The station gives, an average, 5.4 pphm at this site everytime the wind blows from the station to the site. This it does for 430 hours out of 4,127 hours."

(b) On seven occasions in the winter of 1964 the number 2 High Marnham SO_2 measuring station experienced concentrations, attributed to the power plant alone, of more than 25 pphm for periods of 28–60 minutes. On one occasion a concentration of this magnitude lasted for a period of 121–180 minutes.

6. Obviously, a plume emitted aloft into a stable layer can be "shielded" from the ground so long as it remains within the stable layer (e.g., an inversion). The question is whether a high effective stack height insures that the plume will remain in a single layer. If in the normal course of diurnal variation in the depth of the mixing layer, the stability is wiped out up to the level of the plume then the effluents will be mixed to the ground. The frequency of these events and the resulting ground concentrations depend on the climatology of the plant location, the effective stack height for each meteorological situation, and the strength of the source, e.g., plant size. Data from an investigation by the Tennessee Valley Authority supported by the National Center for Air Pollution Control indicate that these "inversion break-up fumigations" have been found to occur more frequently than had been expected and with resulting ground level concentrations on the order of those expected from theory.

By and large the depth to which the mixing layers (which break down stable stratifications) extend are believed to be deeper in all seasons over the United States than over Britain. Some U.S. examples are as follows:

Average depth of mixing layer (afternoon)

	Feet
Pittsburgh:	
July	6,000
December	4,500
Salt Lake City:	
July	14,000
December	2,100

As noted the geographical variation can be very great. A much more complete discussion of the mixing depth concept is contained in the paper by George C. Holzworth, "Mixing Depths, Wind Speeds, and Air Pollution Potential for Selected Locations in the United States," a copy of which is attached. Climatologi-

cal data on the variation of mixing depth for Great Britain are not available, and to our knowledge have not been compiled. Such data would be highly valuable in assessing frequency of the inversion break-up reaching the level of the plume. The results, Stone and Clarke agree (p. 9) can cause concentrations double those for neutral conditions.

In summary, the Stone and Clarke paper has not explored many facets of the meteorology concerned with ground level concentrations of SO_2 emitted from the High Marnham stacks, nor does the limited sampling network allow evaluation at distances more removed from the stack.

MIXING DEPTHS, WIND SPEEDS, AND AIR POLLUTION POTENTIAL FOR SELECTED LOCATIONS IN THE UNITED STATES[1]

George C. Holzworth
Air Resources Field Research Office,[2] ESSA, Cincinnati, Ohio

---

[1]Presented at the American Meteorological Society Conference on Fair Weather Meteorology, Santa Barbara, California, 28 February - 2 March 1967.

[2]National Center for Air Pollution Control, Public Health Service, U. S. Department of Health, Education, and Welfare.

ABSTRACT

Daily estimates of morning and afternoon mixing depths and average wind speeds through the mixing layers were calculated and summarized for seven locations in several climatic regions of the contiguous United States. Mixing depth and wind speed estimates were based on regular surface (airways) and upper-air (rawinsonde) observations of the Weather Bureau and on the assumption of a dry adiabatic lapse rate in the mixing layer. Monthly averages of morning and afternoon mixing depth and wind speed are presented graphically. The frequency of occurrence of various combinations of mixing depth and wind speed classes were used in an urban diffusion model to calculate theoretical values of relative pollutant concentration for four major cities. These relative pollutant concentrations, which also depend upon city size, are compared among the cities on the bases of their current sizes and a common size.

77-515 O-67-pt. 4—5

1. Introduction

Meteorologists at the National Center for Air Pollution Control are developing a quantitative air pollution potential climatology for the contiguous 48 states. Two parameters considered basic to this climatology are (1) the depth above the surface through which pollutants are mixed vigorously and (2) the average wind speed through the mixing layer. Typically, these parameters undergo significant seasonal and diurnal variations, with values highest in the afternoon and lowest in the morning.

For community air pollution considerations, primary interest is in mixing depths and wind speeds over urban areas; usually, however, meteorological observations are made only at airports in rural or suburban surroundings. Since in many respects cities create their own climates (Kratzer, 1956; Landsberg, 1956), especially at night, there are problems in estimating meteorological conditions over cities on the basis of observations made in rural areas.

The mixing depth concept is based upon the principle that heat transferred to the atmosphere at the earth's surface results in convection, vigorous vertical mixing, and establishment of a dry adiabatic lapse rate. The depth through which such mixing extends depends primarily upon the initial vertical temperature structure and the heat input at the surface. Neglecting temperature advection, afternoon mixing depths were calculated from temperatures aloft observed at 1200 GMT and maximum surface temperatures observed from 1200 to 1600 LST.

Afternoon mixing depths in urban and nearby rural areas usually do not differ significantly; however, the differences between nocturnal mixing depths in urban and rural areas are often highly significant. For example, on a clear calm night with an inversion at the surface in a rural area, vertical mixing in the inversion layer cannot be described for the purposes of this study as anything like vigorous; on the contrary, it is practically nonexistent. In such a case there is no mixing layer as defined here. On the other hand, in a nearby city the effect of the nocturnal urban "heat island" (Mitchell, 1962) is to create a mixing layer (Duckworth and Sandberg, 1954; DeMarrais, 1961; Summers, 1965).

Since upper-air soundings are made at 1200 GMT, which is near sunup in the United States, morning mixing depths over an urban area were estimated for the time interval of the morning "rush". Additional reasons for selecting this time were that pollutant emission rates and concentrations of nonreactive pollutants both are usually greatest around morning rush hours. A value for the morning urban mixing depth was calculated by adding 5C to the minimum airport surface temperature observed from 0200 to 0600 LST and assuming a dry adiabatic lapse rate to the intersection of the observed 1200 GMT temperature sounding. The "+5C" factor was based on some comparisons of minimum temperature at urban and nearby rural sites. For the most part, however, it was established arbitrarily to allow for urban-rural differences in surface temperature and for some solar heating of the surface after sunrise.

The other parameter considered important in this study was the wind speed averaged vertically through the mixing depth. This value was calculated as a simple arthmetic average of wind speeds aloft and at the surface. Calculations of morning values were based on speeds aloft at 1200 GMT and average speeds at the surface from 0200 to 0600 LST. Afternoon average speeds were based on winds aloft at 0000 GMT and average surface speeds from 1200 to 1600 LST.

If precipitation occurred during specified 12-hour periods that included a morning or afternoon mixing depth computation, those cases were not included in the present study because of the assumption of a dry adiabatic lapse rate in the mixing layer. Nonprecipitation cases accounted for about 80 percent of all cases. For the main purpose of the present study, climatology of air pollution potential, the nonprecipitation data are considered to be adequately representative of all cases.

All data presented in this paper are for the 5 years 1960-1964.

2. Mixing depths[3]

Fig. 1 shows monthly mean mixing depths for morning and afternoon, calculated for Pittsburgh, Nashville, Columbia, and Dayton. These data are plotted together because of their similarity. Among the four stations mean afternoon mixing depths differ by less than 300 m in most months; mean morning mixing depths differ by less than 200 m in all months.

[3]Previous estimates of monthly mean afternoon mixing depths in the United States have been given by Holzworth (1964). Climatological data on morning (or nocturnal) mixing depths over urban areas are unknown, but a study by Hosler (1961) has shown a high frequency of low-level inversions at night and early morning at most rawinsonde stations in the United States.

Values for afternoon mixing depths show large variations during the year. They are deepest, about 1650-1900 m, during April through August and shallowest, about 700-1000 m, in December and January, with rapid changes in transition months. Values for morning mixing depths vary throughout the year at most of these locations by only about 200 m; in general, maxima occur in March and April and minima occur from July through October.

At New York, Fig. 2, afternoon mixing depths are much like those in Fig. 1, except that from April through October the depths are a few hundred meters shallower at New York. The main feature that distinguishes New York from the locations in Fig. 1 is that morning mixing depths are several hundred meters deeper in New York. The cause of this phenomenon has not been found but it is believed to be due to the influence of nearby water masses.

Fig. 3 shows mean mixing depths at Salt Lake City. Note that afternoon mixing depths are plotted on a folded scale. These morning and afternoon curves differ markedly from those for any of the other stations. In particular afternoon mixing depths change significantly from month to month, varying from 600 m in January to 4150 m in July. Relative to curves for other locations, the afternoon curve indicates an almost continuous transition state.

Morning mixing depths at Salt Lake City differ from those at other locations in being shallower; they vary from only 130 to 400 m, being deepest from February through April. The fact that morning mixing depths are so shallow attests to the frequent occurrence of intense radiation inversions.

Fig. 4 shows mean mixing depths for Los Angeles; these morning and afternoon curves are distinctly different from those for any of the other six stations. Afternoon depths are shallowest from July through September and deepest from January through May and in November. The annual range of monthly mean afternoon values, however, is only about 500 m. Morning mixing depths, on the other hand, are distinguished by a comparatively large range between monthly extremes, from 310 m in December to 785 m in May. The rather small differences between morning and afternoon mixing depths from May through September also constitute a unique feature of the Los Angeles data.

3. Wind speeds

Average wind speeds through morning and afternoon mixing depths are shown in Fig. 5 for Pittsburgh, Nashville, Dayton, and Columbia. Data for these stations are fairly similar, especially in the afternoon. Except for extremes, afternoon speeds range from about 4-1/2 to 8 m sec^{-1} and morning speeds range from about 3 to 6-1/2 m sec^{-1}. Like mixing depths, wind speeds are greater in afternoons than in mornings. Annual variations in the morning and afternoon curves are similar; generally, faster speeds occur from November through April and slower speeds from June through October.

The wind speed data for New York, shown in Fig. 6, display an annual variation that is quite similar to that shown for the four stations in Fig. 5, except that speeds at New York are somewhat faster than at the other locations.

At Salt Lake City, Fig. 6, afternoon speeds vary regularly between 3.5 m sec^{-1} in January and 6.3 m sec^{-1} in May. Morning speeds vary rather irregularly during the year, with extremes of 3.1 m sec^{-1} in January and 5.1 m sec^{-1} in April. In general the annual variation of wind speed at Salt Lake City is quite different from that for New York and other locations to the east.

Fig. 6 also shows wind speeds for Los Angeles; for afternoons these values are similar to those for Salt Lake City, except that speeds in Los Angeles in summer are somewhat slower. Morning values at Los Angeles are characterized by extraordinarily slow speeds, ranging from only about 2 m sec^{-1} from June through October to near 3 m sec^{-1} from January through April.

4. Air pollution potential

Up to this point it has been shown that mean mixing depths and wind speeds vary more or less from place to place, from month to month, and from morning to afternoon. Although the data are interesting in themselves and potentially useful in various meteorological specialties, they will be much more useful in the air pollution field if they can be evaluated in terms of quantitative estimates of the meteorological potential for community air pollution. This can be accomplished now by application of an atmospheric diffusion model for metropolitan areas, a model recently tested against observed pollutant data with good results (Miller and Holzworth, 1966).

In this model the relative pollutant concentration[4] averaged over an urban area is a function of the mixing depth, wind speed, and city size. The model assumes that the pollutants are stable or nonreactive and diffuse vertically from a series of cross-wind line sources until they reach the top of the mixing layer; thereafter, a uniform vertical distribution of pollutants is assumed. Emission rates are assumed uniform over each city, and vertical diffusion coefficients appropriate for morning and afternoon mixing layers are arbitrarily specified.

Thus, from observed frequencies of various combinations of mixing depth and wind speed classes, which were obtained, frequencies of relative concentrations were derived for several cities. Fig. 7 shows the annual cumulative percent frequency of theoretical relative concentrations averaged over Los Angeles, whose size was assumed to be 60 km. City size was defined as the mean distance across the urban area. The figure shows clearly that high relative concentrations are expected more frequently in the morning than in the afternoon, reflecting the diurnal variation of mixing depths and wind speeds. At the low-frequency ends of the curves the highest relative concentrations, about 330 sec m^{-1} or greater, are expected on only about 0.1 percent of the afternoons but on about 5 percent of the mornings. Similarly, at the 50 percentile frequency the relative concentration for afternoons is 18 sec m^{-1}, while that for mornings is 55 sec m^{-1}.

---

[4] Units of relative concentration, χ/Q_A, are sec m^{-1} since units of concentration, χ, are g m^{-3} and those of area emission rate, Q_A, are g m^{-2} sec^{-1}.

Curves like those in Fig. 7 for Los Angeles were also prepared for Salt Lake City, New York, and St. Louis, the latter based on meteorological data at Columbia, Missouri. Table 1 shows average relative concentrations expected to be exceeded 10, 50, and 90 percent of the time, based on current city sizes. Thus, at Salt Lake City, city size 16 km, an average relative concentration of 43 sec m^{-1} or greater is expected on 10 percent of the mornings. Although values in Table 1 may be compared among the different cities, it should be emphasized that these values represent theoretical concentrations relative to emission rates. Pollutant concentrations in each city will depend critically upon the appropriate emission rates. The only comparisons offered in this paper concern the dilution effects due to meteorological conditions and effects due to city size.

For current city sizes the highest relative concentrations for morning and afternoon at all percentiles occur at Los Angeles; these high concentrations are due in part to the large size of that city. Los Angeles values are especially high in the morning; e.g., at Los Angeles 206 sec m^{-1} or greater is expected on 10 percent of the mornings, while the next highest value at any location is 70 sec m^{-1} at St. Louis. It is interesting that at the morning 10 percentile level, relative concentrations at St. Louis and New York are almost equal, although the size used for New York is almost half again as large as that for St. Louis. Similarly, in the morning at the 50 and 90 percentile frequencies, relative concentrations for Salt Lake City and St. Louis are equal although the city-size values differ by a factor of 2. In the afternoon at all percentiles the relative concentrations differ only slightly among the locations, except at Los Angeles, where they are highest.

It is interesting to consider what the relative concentrations would be like if the other cities were all the same size as Los Angeles. Table 2 is the same as Table 1 except that all city sizes are the same as for Los Angeles, 60 km. In the morning at the 10 percentile frequency the highest relative concentration, 206 sec m^{-1}, still would occur at Los Angeles but the next highest value, 147 sec m^{-1}, now would occur at Salt Lake City and the lowest value, 94 sec m^{-1}, would occur at New York. In the morning at the 50 percentile or mean value level, the highest relative concentration, 71 sec m^{-1}, would occur at Salt Lake City, the second highest, 55 sec m^{-1}, would occur at Los Angeles and the lowest, 21 sec m^{-1}, would occur at New York. On an annual basis the mean of average relative concentrations in the morning would be highest at Salt Lake City. At the 90 percentile frequency, morning relative concentrations would be highest at Los Angeles but almost as high at Salt Lake City; values for St. Louis and New York would be somewhat lower.

In the afternoon at the 10 percentile frequency the highest relative concentration, 37 sec m^{-1}, would occur at Salt Lake City but would be only slightly higher than the Los Angeles value, 35 sec m^{-1}. At the 50 percentile frequency the highest afternoon relative concentration still would occur at Los Angeles but values for the other cities would be only slightly lower. Table 2 indicates that for 60-km size cities the annual dispersion conditions at Salt Lake City are generally almost as poor as at Los Angeles; in some respects they are worse. Dispersion conditions at New York generally are better than at any of the other three cities considered.

It should be noted that the foregoing comparisons of frequencies of relative concentrations are made on an annual basis in the interest of space economy. As may be expected from the monthly data on mixing depths and wind speeds, significant variations occur in the seasonal frequencies of relative concentrations.

5. Summary

Monthly mean values of mixing depth and average wind speed through the mixing depth have been shown to vary more or less from place to place in the United States, from month to month, and from morning to afternoon. Frequencies of these parameters together with city sizes have been used in a model of atmospheric diffusion over metropolitan areas to estimate annual cumulative frequency curves of average relative pollutant concentrations for four major cities of various sizes. On the basis of the 50 percentile frequencies and current city sizes, the highest relative concentration in the morning occurs at Los Angeles; values at Salt Lake City and St. Louis are about 1/2 the Los Angeles values and at New York, about 1/3. In the afternoon relative concentrations are lower than in the morning for all cities; relative concentrations are highest at Los Angeles, roughly half again as high as at the other cities. If all cities were the size of Los Angeles, 60 km, the highest relative concentration at the 50 percentile frequency in the morning would be at Salt Lake City, followed in order by Los Angeles, St. Louis, and New York; in the afternoon the highest average relative concentration would be at Los Angeles, with only slightly lower

values at the other cities. Thus, from meteorological considerations dispersion conditions at Salt Lake City are almost as poor as at Los Angeles. Of the four cities considered the best dispersion occurs at New York.

It is planned to further develop and extend this air pollution potential work to other locations in the United States, ultimately providing an urban air pollution potential climatology for the United States.

References

DeMarrais, G. A., 1961: Vertical temperature differences observed over an urban area. Bull. Amer. Meteor. Soc., 42, 548-554.

Duckworth, F. S., and J. S. Sandberg, 1954: The effect of cities upon horizontal and vertical temperature gradients. Bull. Amer. Meteor. Soc., 35, 198-207.

Holzworth, G. C., 1964: Estimates of mean maximum mixing depths in the contiguous United States. Mon. Wea. Rev., 92, 235-242.

Hosler, C. R., 1961: Low-level inversion frequency in the contiguous United States. Mon. Wea. Rev., 89, 319-339.

Kratzer, P. A., 1956: The Climate of Cities; translated by Amer. Meteor. Soc. under contract no. AF 19(604)-6113, Armed Services Technical Information Agency, Arlington 12, Virginia, 220 pp.

Landsberg, H. E., 1956: The climate of towns; in: Man's role in changing the face of the earth, Chicago, Univ. of Chicago Press, 584-606.

Miller, M. E., and G. C. Holzworth, 1967: An atmospheric diffusion model for metropolitan areas. J. Air Poll. Cont. Assoc., 17, 46-50.

Mitchell, J. M., Jr., 1962: The thermal climate of cities; in: Air over cities, SEC Tech. Rpt. A62-5, Public Health Service, Cincinnati, Ohio, 131-145.

References (continued)

Summers, P. W., 1965: An urban heat island model; its role in air pollution problems with application to Montreal. Presented at the First Canadian Conference on Micrometeorology, Toronto, 12-14 April 1965.

Table 1.

Theoretical relative concentrations (sec m^{-1}, averaged over each city area) expected to be equalled or exceeded 10%, 50%, and 90% of the time annually, based on current city sizes.

	Morning			Afternoon		
	10%	50%	90%	10%	50%	90%
Salt Lake City - 16 km	43	23	15	16	11	10
St. Louis - 32 km	70	23	15	16	12	10
New York - 45 km	66	19	16	18	13	12
Los Angeles - 60 km	206	55	25	35	18	14

Table 2.

Theoroetical relative concentrations (sec m^{-1}, averaged over each city area) expected to be equalled or exceeded 10%, 50%, and 90% of the time annually, based on a common city size of 60 km.

	Morning			Afternoon		
	10%	50%	90%	10%	50%	90%
Salt Lake City - 60 km	147	71	22	37	16	13
St. Louis - 60 km	127	37	17	22	15	12
New York - 60 km	94	21	16	22	14	12
Los Angeles - 60 km	206	55	25	35	18	14

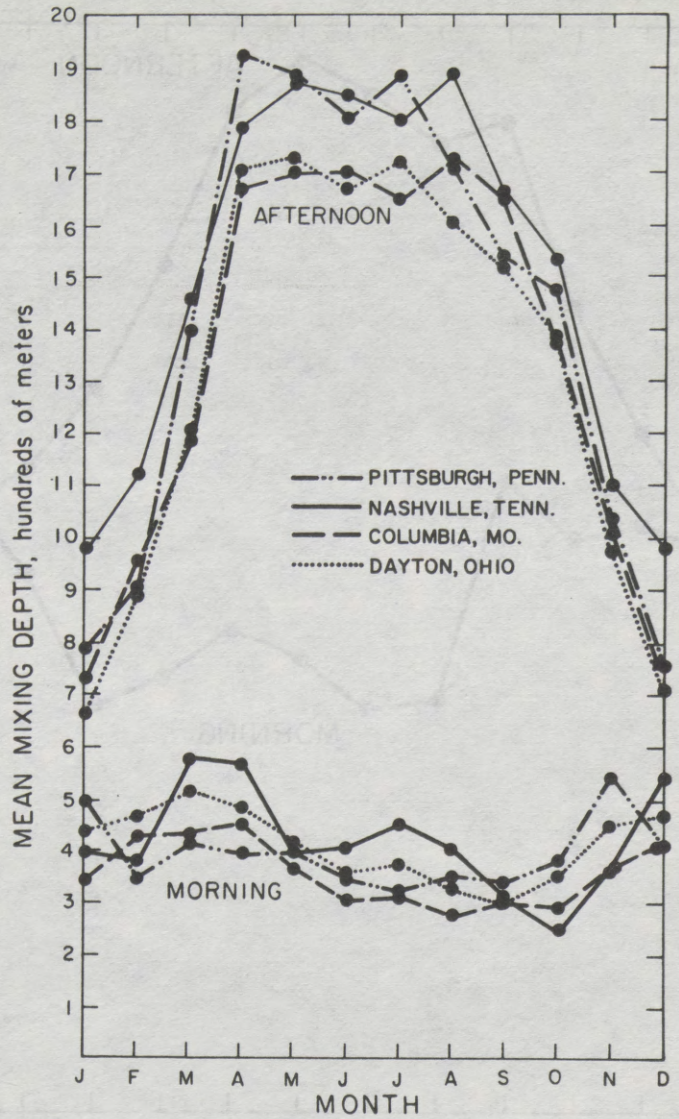


Fig. 1. Monthly mean mixing depths at Pittsburgh, Pennsylvania; Nashville, Tennessee; Columbia, Missouri; and Dayton, Ohio; 1960-1964.

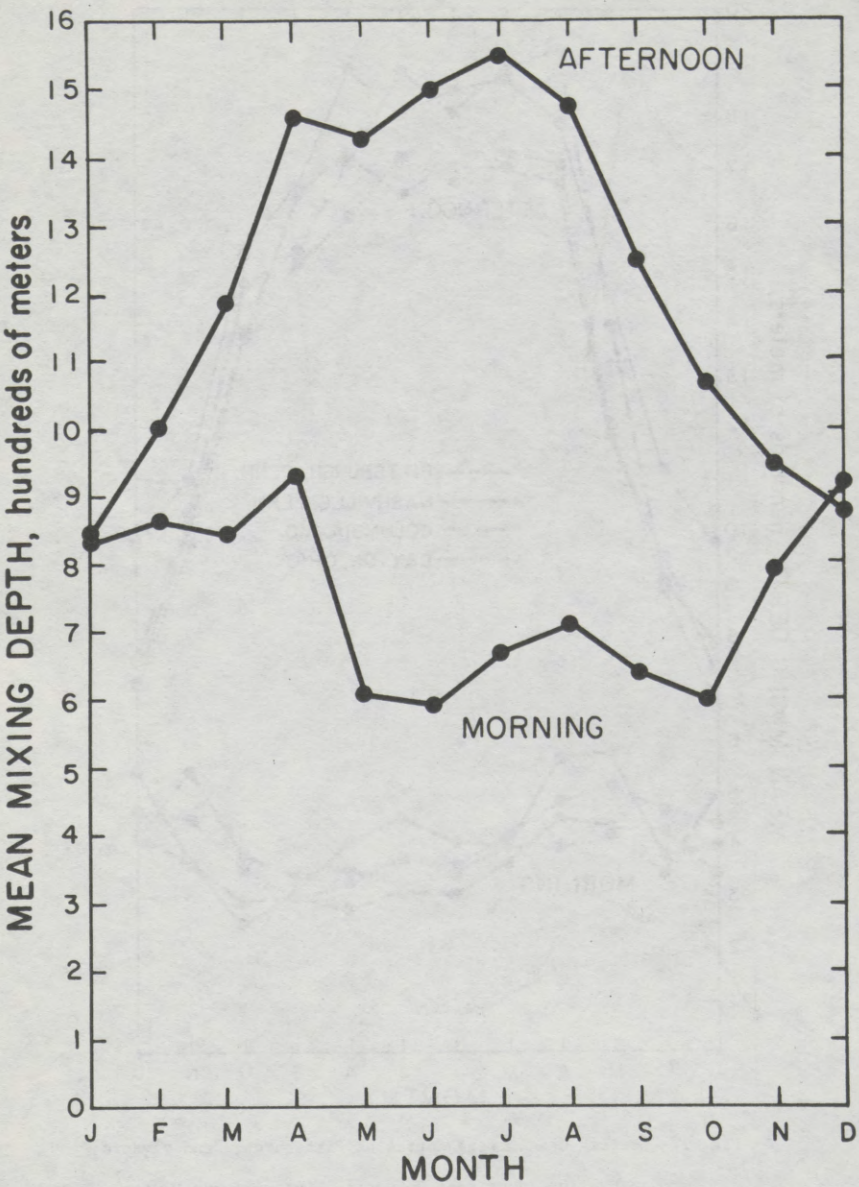


Fig. 2. Monthly mean mixing depths at New York, New York; 1960-1964.

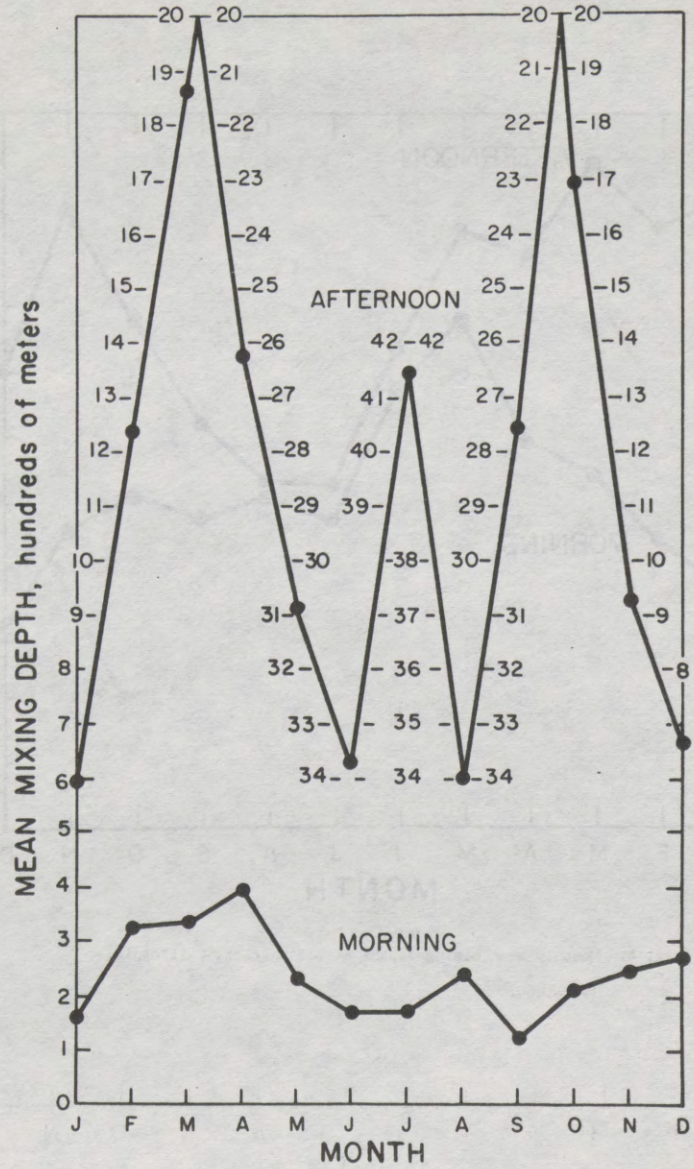


Fig. 3. Monthly mean mixing depths at Salt Lake City, Utah; 1960-1964.

Note folded ordinate scale.

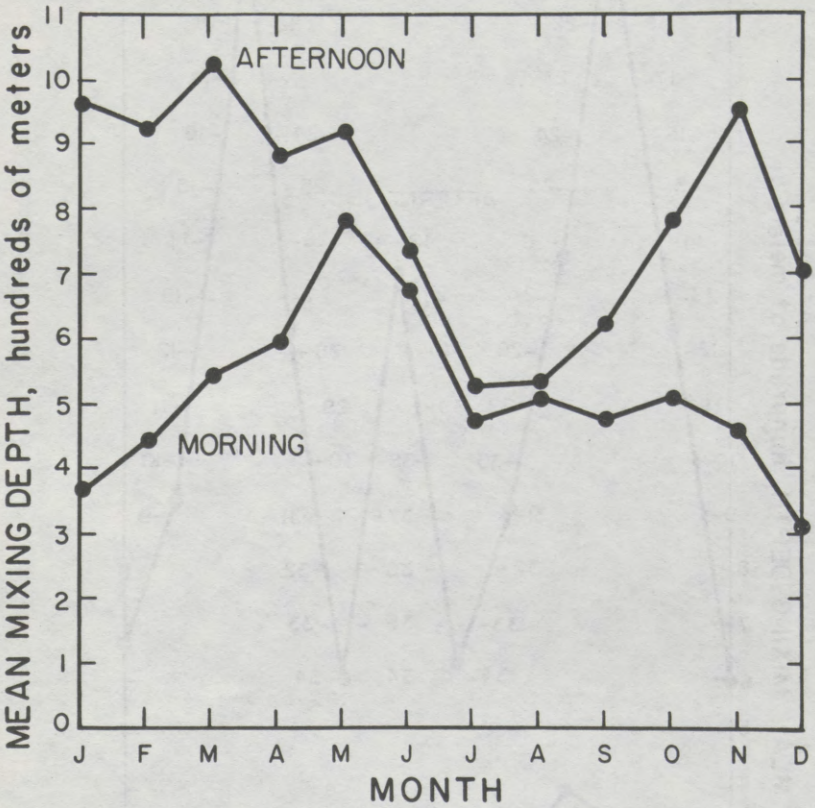


Fig. 4. Monthly mean mixing depths at Los Angeles, California; 1960-1964.

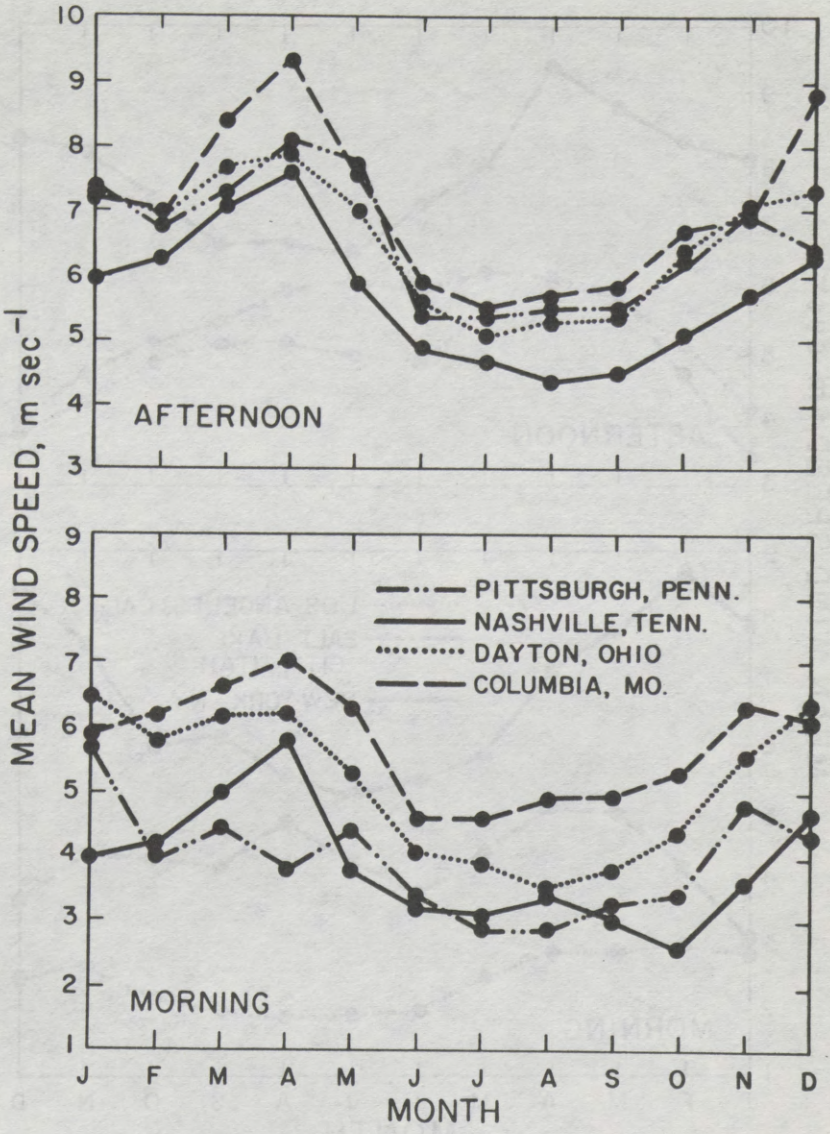


Fig. 5. Monthly mean values of the average wind speed through the mixing layer at Pittsburgh, Pennsylvania; Nashville, Tennessee: Columbia, Missouri; and Dayton, Ohio; 1960-1964.

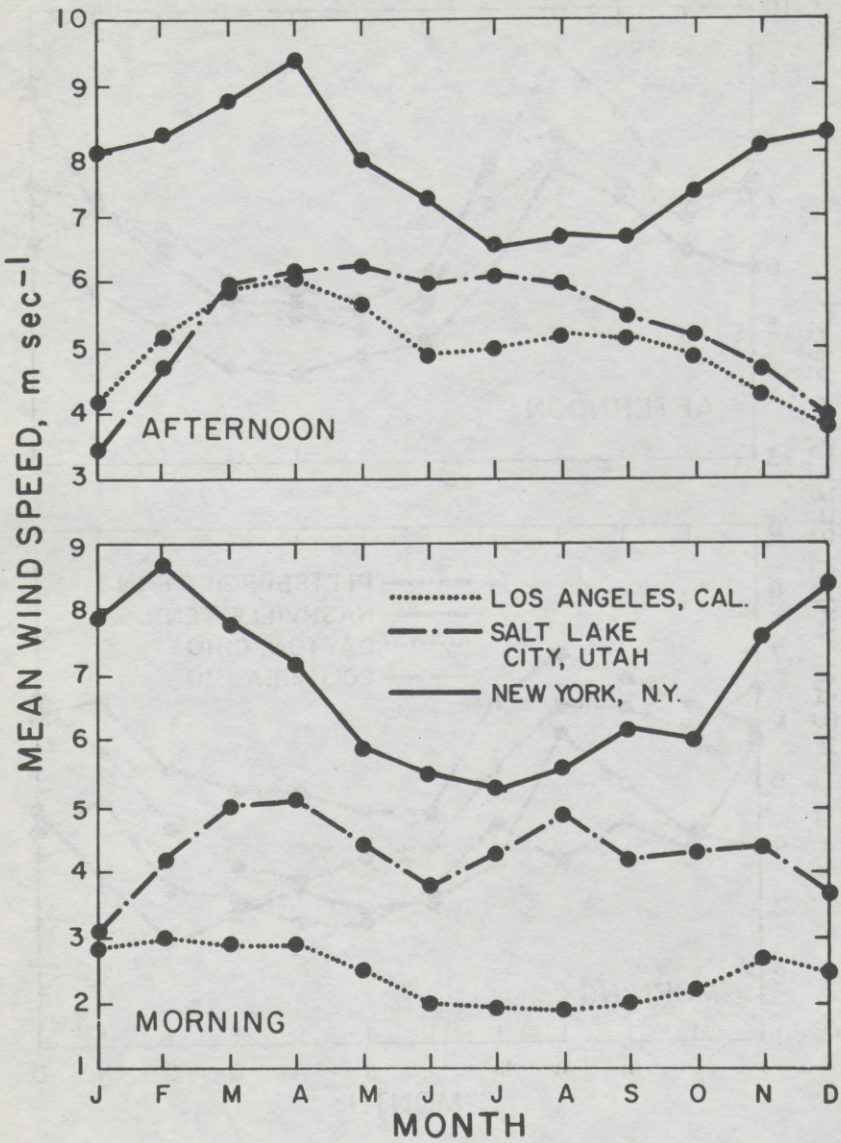


Fig. 6. Monthly mean values of the average wind speed through the mixing layer at New York, New York; Salt Lake City, Utah; and Los Angeles, California; 1960-1964.

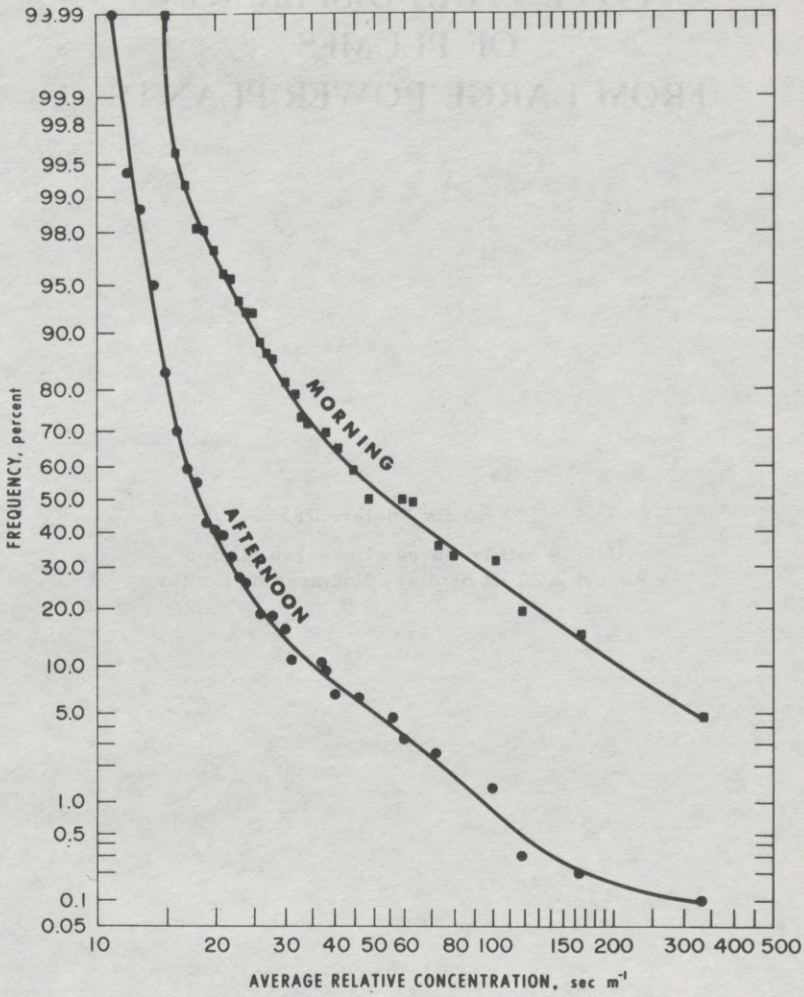


Fig. 7. Annual frequency of theoretical relative pollutants concentrations (averaged over the Los Angeles area) equal to or greater than abcissa values.

POTENTIAL DISPERSION OF PLUMES FROM LARGE POWER PLANTS

Francis Pooler, Jr.

U.S. Weather Bureau Research Station
Robert A. Taft Sanitary Engineering Center

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Division of Air Pollution
Cincinnati, Ohio

1965

ABSTRACT

Expected ground-level concentrations resulting from emissions from large power plants are discussed for three meteorological situations considered to be most likely to result in significant air pollution concentrations. These situations are (1) high wind; (2) inversion breakup; and (3) limited mixing layer with a light wind. Effects of increasing stack height are discussed for each situation. Numerical examples based on calculations included as an appendix are shown.

POTENTIAL DISPERSION OF PLUMES FROM LARGE POWER PLANTS

Dispersion of effluent from large power-generating plants must be considered on the basis of individual plants. Although diffusion formulae for comparatively small sources have been at least partially checked against actual dispersion, similar extrapolations from existing data probably cannot be applied to estimates of pollutant emissions from plants in the range of 1000- to 5000-megawatts capacity. Plants of such sizes emit heat at a rate equivalent to the net heating by the sun over an area many hundreds or thousands of meters in diameter; it is evident that such a source will set up its own circulation pattern in the air, at least in the immediate vicinity of the plant. Most of the time the effluent plume will rise far above the ground, and its only influence on air quality will be to increase the surface concentrations of pollutants in the air mass downwind by some rather small amount. If significant background pollution levels exist, however, even a small addition to the background concentration could introduce a pollution problem.

It is assumed that any new plant will be designed to meet two engineering criteria to prevent pollution in the immediate vicinity of the plant. First, the stacks will be tall enough to prevent aerodynamic downwash caused by large obstacles to the air flow. This criterion can be met by following the "2-1/2" rule, which states that a stack should be at least 2-1/2 times the height of any nearby obstacles to the flow. Because a large power plant requires a large building, the minimum stack height imposed by this criterion alone will be several hundred feet. Second, the exit speed of gases from the stack and design of the chimney top should be adequate to prevent entrainment of effluent into the turbulent wake of the stack. Generally, an exit speed in excess of the wind speed will minimize this problem. Since both criteria evolve from aerodynamic considerations, the adequacy of the plant design can be tested by wind-tunnel models.

If it is assumed that these engineering criteria are met, then estimating potential pollution from large plants narrows to a consideration of relatively infrequent weather conditions (conditions that do occur, however) that can bring about ground-level fumigations: high winds, inversion breakup, and a limited mixing layer with light winds. The frequency of these adverse conditions will determine the magnitude and frequency of the potential pollution.

The following discussion of these three types of fumigation is illustrated numerically in Figures 1 through 3. The calculations on which these figures are based are included as an appendix. The models of plume dispersion used were based on the experience of and data collected by TVA personnel (Gartrell et al. 1964), as well as on the author's personal observation of the behavior of plumes from large heat sources. These models were first used in conjunction with climatological data

of the Oak Ridge, Tennessee, area (Holland, 1953) as an informal cross-check on calculations then being made by TVA personnel to determine the stack height required for a proposed new generating plant (Thomas et al., 1963). The conclusions regarding required stack height were the same for both methods of calculation. The exact assumptions used to obtain the numerical values shown by the figures are not critical in this discussion; the principal purpose here is to suggest the meteorological factors that influence dispersion and should be considered in location and design of large power plants.

HIGH-WIND FUMIGATION (Figure 1)

High-wind fumigation occurs when the dilution of effluent by motions in the air--longitudinal dilution due directly to wind speed, and transverse dilution by eddies, the magnitude of which is a function of wind speed--is sufficient to overcome the tendency for a heated plume to accelerate upward as the result of buoyancy forces. With sufficiently rapid dilution, the plume continuously decelerates vertically, and an effective plume rise can be computed. The larger the source, the greater the wind speed necessary to cause this vertical deceleration throughout the entire plume volume. Although a precise relationship between plant

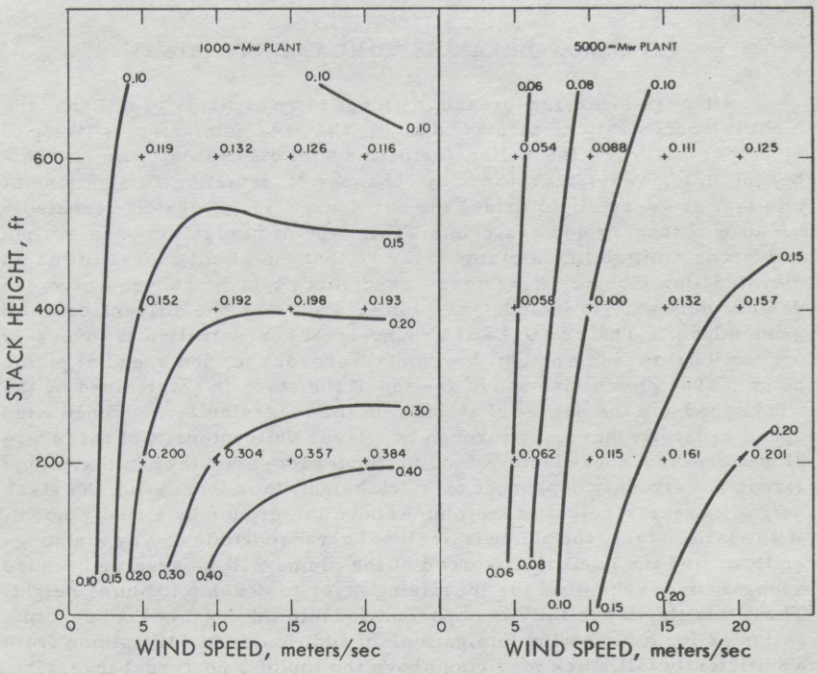


Figure 1. Estimated ground-level SO_2 concentrations (ppm) in high-wind, neutral stability conditions. (Sulfur content of coal is assumed to be 1%; for other sulfur contents, value would be changed proportionately. Values represent 1/2 hour averages. To approximate 3-minute average, multiply by 2.5; to approximate 2-hour average, multiply by 0.5.)

capacity and this "critical" wind speed is not known, it is probable that the critical speed for a 1000-Mw plant would be about 25 mph (13 meters/sec), and for a 5000-Mw plant, about 40 mph (20 meters/sec), if all emissions are assumed to come from a single stack. At wind speeds less than critical, an increasing proportion of the plume should rise at a rate determined principally by buoyancy forces; the dilution of this part of the plume is determined by its upward motion as much as by ambient turbulence. Plume rise with such a divergent plume is difficult to define, and the concept of a coherent plume should probably be discarded in favor of a formulation in which the stabilized portion of the plume is considered, rather than the rising portion. The particular formulations for "plume rise" and plume dispersion were selected only because they are widely used; the numerical results probably do show reasonable trends, even though they should be valid, if at all, only for wind speeds in excess of "critical." The implication is that for plants of large enough capacity, the concentrations in a high-wind fumigation probably depend only on stack height and emission conditions, and thus maximum concentrations from a 5000-Mw plant would be only slightly above those from a 1000-Mw plant (with all emissions from a single stack).

INVERSION-BREAKUP FUMIGATION (Figure 2)

Although inversion-breakup fumigation is likely to produce the highest concentrations at ground level, the area fumigated is likely to be a long, narrow ribbon-like formation with its closest point a number of miles away; therefore, the chances of detecting fumigations of this type are very slight unless the same area is fumigated repeatedly because of topographic restraints. This type of fumigation occurs when effluent is emitted into a stable layer so that the plume moves off as an elevated flat ribbon. A surface-based mixing layer subsequently develops, builds up to include the plume, and stirs the effluent down to ground level. The resultant ground-level concentration is inversely proportional to plume height, horizontal spread, and wind speed at plume height. The plume rise above the top of the stack is determined by the wind speed and the degree of stability in the inversion layer. Since wind speed generally increases through this layer while intensity of the inversion decreases, these factors tend to counteract each other so that plume rise is not strongly dependent on stack height; thus increasing the stack height increases height of the plume above the ground by a like amount. With a taller stack, the plume is likely to be transported away by a stronger flow, and the horizontal spread of the plume will be greater because a longer time is required for the mixing layer to develop to plume height. Thus, tall stacks are fully as important for minimizing this kind of fumigation as for a high-wind fumigation. In addition, since the plume from a sufficiently tall stack may rise above the top of a nocturnal inversion, the frequency of inversion-breakup fumigations is reduced with taller stacks. Under inversion conditions an increase of plant size will result in a proportionately smaller increase of plume rise than under high-wind conditions; thus, the maximum concentrations should increase as plant capacity is increased, but at a less than linear rate.

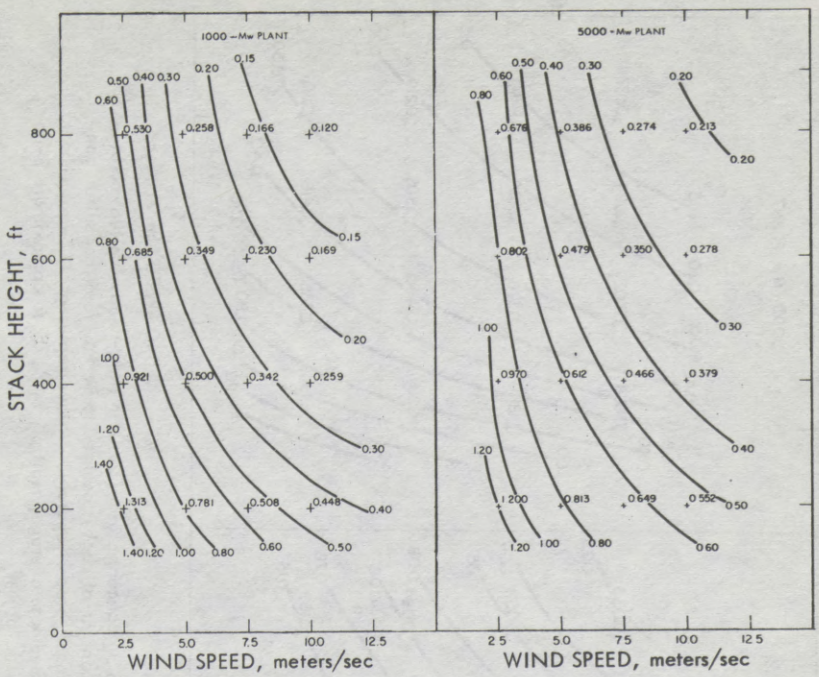


Figure 2. Estimated ground-level SO_2 concentrations (ppm) in inversion-breakup fumigation. (Sulfur content of coal is assumed to be 1%; for other sulfur contents, values would be changed proportionately. Values represent 1/2- to 1-hour averages.)

FUMIGATION IN A LIMITED MIXING LAYER WITH LIGHT WINDS (Figure 3)

Fumigation in a limited mixing layer with light winds occurs when effluent is contained within too small a mixing volume. Under these circumstances, the plume will rise to the top of the surface-based mixing layer (up to the base of the inversion), which may be up to thousands of feet deep, and then diffuse and subside to ground level at a rate determined by the rate of convective overturning brought about by solar heating of the ground. Stack height has essentially no effect on fumigations of this kind. The ground-level concentration after some time will be given by emission rate divided by the product of mixing height, mean wind speed, and cross-wind spread. The time after which such a computation becomes meaningful is that required for the effluent to mix and subside to ground level. With a relatively small plant, this subsidence begins almost immediately after the plume has risen to the top of the mixing layer; with increasing plant size, a greater fraction of the plume will still be warmer and therefore less dense than the air through which it rose, and thus will stabilize at some short distance above the mixing

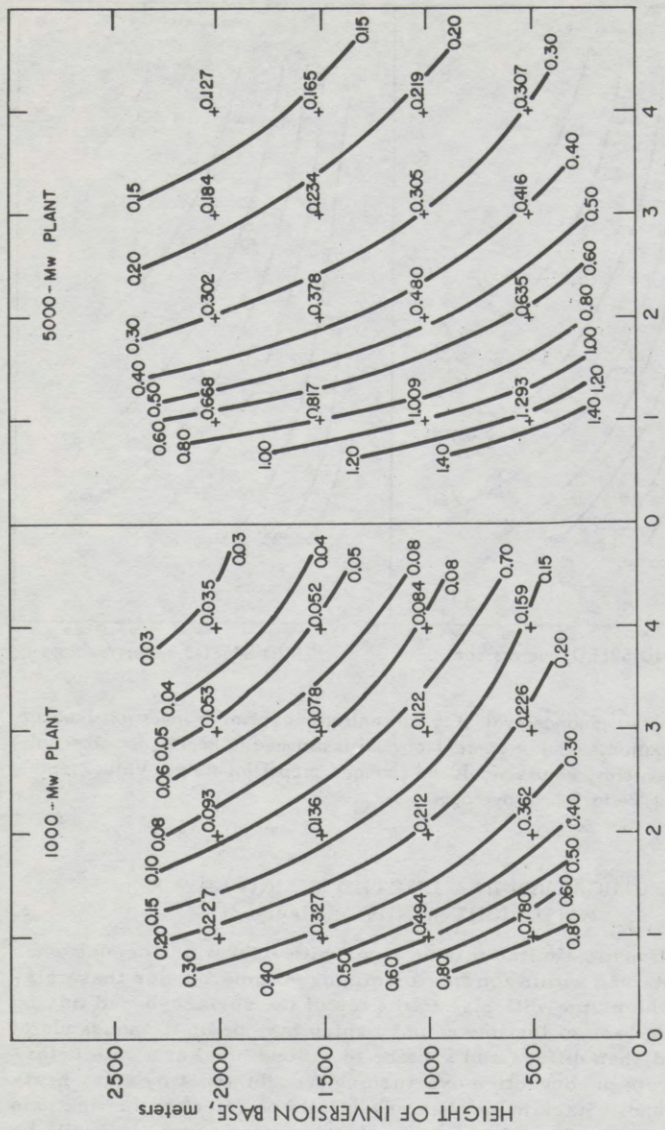


Figure 3. Estimated ground-level SO_2 concentrations (ppm) in light-wind, limited-mixing-depth conditions. (Sulfur content of coal is assumed to be 1%; for other sulfur contents, values would be changed proportionately. Values represent 1/2- to 1-hour averages. To approximate 3-minute average, multiply by 1.75; to approximate 2- to 3-hour average, multiply by 0.75.)

layer or within the capping stable layer. The plume will be released into the mixing layer as that layer develops greater depth, thus introducing a time-delay factor, which increases with increasing plant size. In consequence, the maximum ground-level concentration with this kind of fumigation increases with plant size at a less than linear rate, but the area fumigated increases in direct proportion to plant size.

The experience of the TVA with their many steam-generating plants illustrates some of these situations. As plants of increasingly larger capacity have been built, with correspondingly taller stacks, the fumigations have shifted from the high-wind type, with which many people are most familiar, to the light-wind type. Although tall stacks can be built to minimize the high-wind and inversion-breakup fumigations, the total pollution discharge of the larger plants becomes a problem when the limited capacity of the mixing layer prevents adequate dilution. Thus, the other element that determines concentrations, the pollutant source strength, must be controlled if such large plants are to be built in parts of the country where this type of fumigation occurs with any appreciable frequency. Although conditions of this type are most frequent in Southern California, no section of the country can consider itself immune from such problems if the pollution sources are present.

LOCAL EFFECTS

Local factors may exert some influence on each of these types of fumigation. Since large power plants are built adjacent to sources of cooling water, there are invariably some topographic complications that must be considered. With both high-wind and inversion-breakup fumigations, the more elevated points in the areas affected will experience higher concentrations than would be found over flat terrain. For the high-wind fumigation comparatively large-scale topographic features, such as a small mountain upwind or an extensive water surface downwind, can create a mean downflow that lowers the plume as it moves downwind. For the inversion-breakup fumigation, large-scale channelling such as found with the Trail, B.C., smelter (Hewson and Gill, 1944) may confine the plume to a selected path and lead to repeated local fumigations. In other areas a stable layer may flow over a much warmer region, e.g., from water to land in the summer or from the outskirts of a large city over the city itself, and lead to an inversion-breakup fumigation because of a spatial transition of the flow. For the light-wind fumigation a large, cool surface, such as a lake, will always be a favored region for subsidence, so that the downwind shore may experience more frequent and severe fumigations than any surrounding areas.

The dispersion potential for a large power plant must be calculated from a consideration of the locale into which the plant is to be fitted, and thus the details of location and design must be treated individually. Meteorological control of plant operations may be required when potential pollution cannot be minimized by any other methods.

APPENDIX

Formulae and Numerical Values Used in Calculating Maximum Ground-Level Concentrations

(All symbols and numerical values are listed and defined in Table A1.)

Atmospheric pressure of 1000 mb and temperature of 15°C were assumed for all calculations. The emission rate of heat to the atmosphere was assumed to be 15 percent of the plant generating capacity, with an emission temperature of 140°C and a stack efflux speed of 20 meters per second. From mass continuity with these assumptions, the stack diameter for a 1000-Mw plant is 9.565 meters. With an assumed coal consumption rate of 383 tons per hour for a 1000-Mw plant, with full conversion of the sulfur to SO_2 and its emission to the atmosphere, the SO_2 emission rate is 1.932×10^3 p grams per second. For a 5000-Mw plant, the heat and SO_2 emission rates were multiplied by 5, and the stack diameter by $5^{1/2} = 2.236$. All calculations were for p = 1 percent; the concentrations shown in Figures 1, 2, and 3 should be multiplied by p for other sulfur contents.

HIGH WIND, NEUTRAL FUMIGATION (Figure 1)

Plume rise was calculated from Holland's formula,

$$\Delta h = \frac{1.5 V_s d_s + 0.409 \times 10^{-4} Q_H}{u} \tag{1}$$

and the maximum ground-level concentration from Sutton's equation,

$$X_m = \frac{2Q}{\pi e u h^2 \rho_{SO_2}}. \tag{2}$$

Calculations were made for four wind speeds - 5, 10, 15, and 20 meters per second; and for three stack heights - 200, 400, and 600 feet. Concentrations at intermediate values were obtained by graphical interpolation.

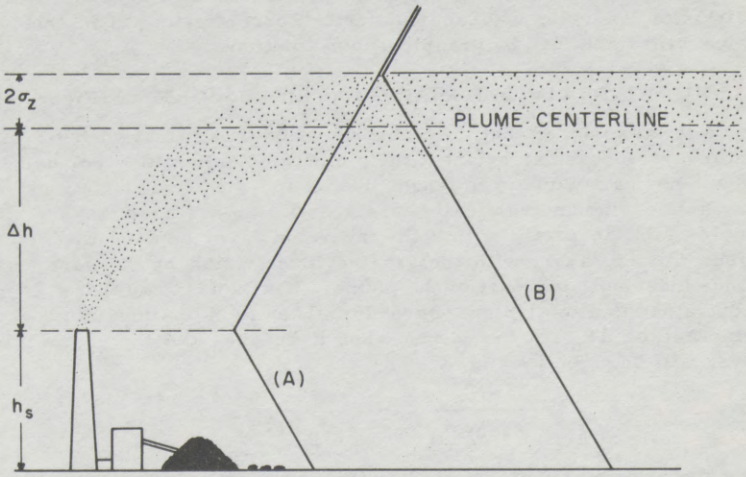
INVERSION BREAKUP FUMIGATION (Figure 2)

A formula for plume rise was developed from dimensional considerations:

$$\Delta h = \left[\frac{\pi \Delta \rho g d_s^2 v_s T a}{4 \rho_a \frac{\delta \Theta}{\delta z} u (u + v_s)^2} \right]^{1/2} \tag{3}$$

It was assumed that the effluent plume rises some distance through the inversion layer and becomes stabilized with the plume centerline a distance Δh above the top of the stack. Thereafter, as the plume moves downwind, it widens with downwind travel but the depth is constant. It was assumed that the maximum ground-level concentration occurs when the plume elements emitted at the time that a surface-based mixing layer

has developed just to stack-top level are later mixed to ground level as the mixing layer builds up to plume level, resulting in the minimum time after emission for plume travel within the inversion layer. It was assumed that the mixing layer would have to develop to the top of the plume, defined here as $2\sigma_z$ above the plume centerline (see Figure A1). The



(A) Temperature profile at time of emission. ($t = o$)

(B) Temperature profile at time of fumigation. ($t = t_m$)

Figure A1.

net amount of heating of the mixing layer required (proportional to the area enclosed between curves A and B) is given by

$$q = \rho_a c_p \frac{\delta \Theta}{\delta z} (\Delta h + 2\sigma_z)(h_s + 1/2\Delta h + \sigma_z). \tag{4}$$

This heating is given by the product of net heating rate of the air by solar radiation multiplied by the time required to develop the mixing layer, or

$$q = Rt_m. \tag{5}$$

Solving (4) and (5) for t_m, the distance x at which the maximum ground-level concentration will occur can be obtained from $x = ut_m$. The maximum concentration was computed by assuming that the plume would then become uniformly mixed through the depth of the mixing layer, with a Gaussian horizontal distribution appropriate to that distance, or

$$X_m = \frac{Q}{\sqrt{2\pi}\, u\, H\sigma_y \rho SO_2}, \tag{6}$$

where $H = h_s + \Delta h + 2\sigma_z$, with σ_z assumed to be 30 meters for the 1000-Mw plant and 45 meters for the 5000-Mw plant; and $\sigma_y = C_y (x + x_v)^{\frac{2-n}{2}}$,

77-515 O-67-pt. 4—7

where $x_v = \frac{\sigma y}{Cy}^{\frac{2}{2-n}}$ at t = 0. Values of $C_y = 0.05657\ m^{1/8}$ and n = 0.25 were assumed. Initial plume widths were represented by assuming σ_y = 60 meters and σ_y = 120 meters for the 1000-Mw and 5000-Mw plants, respectively, at t = 0. For each plant size, calculations were made for wind speeds of 2.5, 5.0, 7.5, and 10.0 meters per second, for stack heights of 200, 400, 600, and 800 feet. Concentrations at intermediate values were obtained by graphical interpolation.

LIGHT-WIND, LIMITED MIXING LAYER FUMIGATION (Figure 3)

It was assumed that the plume rises and tilts so that when it reaches the inversion base at height H the plume element emitted per unit time is a binormal cylinder of length u, and the standard deviations, both across the wind and vertically, are σ_H. It was assumed that the plume would stabilize partly within the inversion layer capping the surface-based mixing layer, with the greatest penetration by the warmest and hence most polluted part of the plume. If it is assumed that $\sigma_H = \frac{\pi}{18} H$ (equivalent to a total plume spread of about 40°), the maximum excess temperature ΔT_m in the plume when it reaches the top of the mixing layer will be given by

$$T_m = \frac{Q_H}{2\pi\rho_a c_p u \sigma_H^2} = \frac{162\ Q_H}{\pi 3\ \rho_a c_p u H^2}. \tag{7}$$

The mixing layer must be heated by this same amount to release the total amount of effluent from the stable layer (see Figure A2). The height of

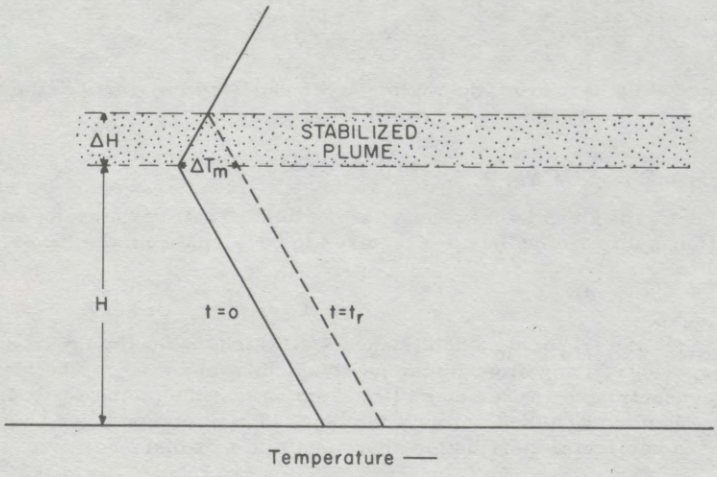


Figure A2.

stabilization above the inversion base of any plume element will be proportional to the excess temperature of the element, and inversely proportional to the stability of the layer. The maximum penetration ΔH will thus be given by

$$\Delta H = \frac{\Delta T_m}{\frac{\delta \Theta}{\delta z}} \tag{8}$$

The effluent will be uniformly distributed in the layer from H to $(H + \Delta H)$.

For the plume elements at $(H + \Delta H)$ to become re-incorporated into the mixing layer, the mixing layer must increase in depth by an amount ΔH, or the temperature of the mixing layer must be increased by T_m. If ΔH is small compared to H, the required heating per unit area of surface is given by

$$q = H \rho_a c_p \Delta T_m \tag{9}$$

Also $q = Rt_r$. Hence,

$$t_r = \frac{\rho_a c_p H \Delta T_m}{R} = \frac{162 Q_H}{\pi^3 uHR} \tag{10}$$

It was further assumed that, once released, the plume elements subside and mix back to ground level according to a vertical velocity distribution $\frac{dz}{dt} = 0.5 + 0.001z$. Integrating, the subsidence time t_s is given by

$$t_s = 1000 \ln(1 + 0.002H) \tag{11}$$

The maximum ground-level concentration when the total plume is stirred back to ground level is given by

$$X_m = \frac{Q}{\sqrt{2\pi}\, u H \sigma_y \rho_{SO_2}} \tag{12}$$

where $\sigma_y = C_y \left[u(t_r + t_s) + x_v\right]^{\frac{2-n}{2}}$; values of $C_y = 1.00\, m^{1/4}$, $n = 0.50$ were assumed, whence $x_v = (\sigma_H)^{1.33}$

Calculations of X_m were made for wind speeds of 1, 2, 3, and 4 meters per second, and mixing layer depths of 500, 1000, 1500, and 2000 meters. Concentrations at intermediate values were obtained by graphical interpolation.

The maximum (centerline) ground-level concentration X_t for a time of travel t other than $(t_r + t_s)$ as a fraction of the maximum concentration is given by

$$\frac{X_t}{X_m} = \frac{(t - t_s)}{t_r} \left[\frac{u(t_r + t_s) + x_v}{ut + x_v}\right]^{0.75} \quad \text{for } t_s \leq t \leq (t_r + t_s) \tag{13a}$$

$$\frac{X_t}{X_m} = \left[\frac{u(t_r + t_s) + x_v}{ut + x_v}\right]^{0.75} \quad \text{for } t \geq (t_r + t_s) \tag{13b}$$

$$X_t = 0 \quad \text{for } t \leq t_s \tag{13c}$$

These equations could also be expressed in terms of distance through the equality $x = ut$. Together with Equation (12), these equations show that for a given set of meteorological conditions (u, H, and R), the ground-level concentration initially increases with travel time t at the same rate for all plant sizes; however, the larger the plant, the longer the travel time over which ground-level concentration increases, and hence the higher the maximum concentration.

Table A1. DEFINITIONS AND DIMENSIONAL UNITS OF SYMBOLS AND NUMERICAL VALUES

c_p	specific heat of air at constant pressure, 0.240 cal g^{-1} $^oK^{-1}$.
C_y	horizontal diffusion coefficient, $(\text{meters})^{\frac{n}{2}}$.
d_s	stack diameter, meters.
e	base of natural logarithms, 2.71828....
g	acceleration of gravity, 9.806 m sec^{-2}.
h	$(=h_s + \Delta h)$ plume height above ground, meters.
h_s	stack height, meters.
Δh	plume rise, meters.
H	depth of mixing layer, meters.
ΔH	increase in depth of mixing layer, meters.
n	dimensionless exponent related to distance-dependence of diffusion rate.
p	percentage sulfur in coal.
q	net heating of an air column, cal m^{-2}.
Q	emission rate of SO_2, g sec^{-1}.
Q_H	emission rate of heat, cal sec^{-1}.
R	net rate of sensible heating of an air column by solar radiation, assumed constant equal to 0.4 Langleys min^{-1} = 66.67 cal m^{-2} sec^{-1}.
t	travel time, seconds.
t_m	time required for mixing layer to develop to top of plume, seconds (for inversion breakup).
t_r	time required for mixing layer to develop to top of plume, seconds (for light wind).
t_s	time required for plume elements to descend from top of mixing layer to the surface, seconds (for light wind).
T_a	ambient air temperature, assumed constant at 15°C = 288.16°K.
ΔT_m	maximum temperature difference between plume elements and surroundings, °C (for light wind).
u	wind speed, m sec^{-1}.
v_s	stack exit speed, m sec^{-1}.

x travel distance, meters.

x_v virtual travel distance to represent initial plume spread, meters.

$\frac{\delta\theta}{\delta z}$ vertical potential temperature gradient, $^{o}C\ m^{-1}$; assumed constant at $1.96 \times 10^{-2}\ ^{o}C\ m^{-1}$ for inversion breakup.

π constant, 3.14159....

ρ_a ambient air density, assumed constant at $1.209 \times 10^{3}\ g\ m^{-3}$.

$\Delta\rho$ density difference between stack effluent and ambient air, assumed constant at $0.3658 \times 10^{3}\ g\ m^{-3}$.

ρ_{SO_2} density of SO_2 at ambient conditions, assumed constant at $2.671 \times 10^{-3}\ g\ cm^{-3}$.

σ_H vertical and crosswind standard deviations of plume distribution at height H, meters (for light wind).

σ_y crosswind standard deviation of plume distribution, meters.

σ_z vertical standard deviation of plume distribution, meters.

X_m maximum ground level concentration, ppm (vol).

X_t centerline ground level concentration at travel time t, ppm (vol).

REFERENCES

Gartrell, F. E., Thomas, F. W., Carpenter, S. B., Pooler, F. Jr., Turner, D. B., and Leavitt, J.M. (1964) Full-Scale Study of Dispersion of Stack Gases - A Summary Report. Tennessee Valley Authority, Chattanooga, Tennessee.

Hewson, E. W., and Gill, G. C. (1944). Meteorological Investigations in Columbia River Valley near Trail. Part II of Report Submitted to the Trail Smelter Arbitral Tribunal, U. S. Bureau of Mines Bulletin 453. Government Printing Office, Washington.

Holland, J. Z. (1953) A Meteorological Survey of the Oak Ridge Area, ORO-99. U.S. Atomic Energy Commission, Oak Ridge, Tennessee.

Thomas, F. W., Carpenter, S. B., and Gartrell, F. E. (1963) Stacks-How High? Journal of the Air Pollution Control Association 13: 198-204.

Senator MUSKIE. What funds has PHS allocated to the Bureau of Mines for its work on the alkalized alumina process? How much of the additional $4.2 million requested by the President for fiscal year 1967 will be allocated to the Bureau of Mines for this purpose? How much of the additional $15 million in fiscal year 1968?

Dr. LUDWIG. Funds have not yet become available from the $4.2 million requested. The point here is that, in addition to the money that has been allocated to the Bureau of Mines for the testing of their process this year, we are supporting about another $400,000 or $500,000 of research by contract in the development of better catalysts, which is a very critical economical problem in the use of this process, and also in the study of additional contacting systems. In addition to the falling bed system, we are looking at the fluid bed system as a possible alternative.

Senator MUSKIE. Senator Baker asked me to direct this question. In your statement you say this:

> This year we have allocated about $6 million for sulfur oxides control work, about $5.5 million of which is in contract work with private organizations or other governmental agencies.

Can you provide the details of these expenditures for the record?

Dr. LUDWIG. Yes, sir; we can do that.

Senator MUSKIE. All right.

(Subsequently, the following information was submitted:)

A summary of funds allocated for sulfur oxides control projects in Fiscal Year 1967 is attached. Also attached, in response to a request from the Subcommittee staff, is a table showing budget allocations for in-house research and development on air pollution control technology by the Public Health Service during the past ten years and the amounts furnished the Bureau of Mines of the Department of the Interior during the same period.

Summary of funds allocated for SO_2 control projects, fiscal year 1967

	Cost
Fiscal year 1967 regular budget:	
Pyrite-coal combustion	$489,000
Limestone-based processes	1,118,000
Alkalized alumina	973,000
Molten carbonate	420,000
New control processes	400,000
Total	3,400,000
Fiscal year 1967 supplemental:[1]	
New control processes	1,400,000
Systems and economic studies	1,000,000
Control processes-smelters, refineries, etc	300,000
Total	2,700,000
Grand total	6,100,000

[1] Projects and related activities for the areas listed in the supplemental are being developed.

SO_2 control project list

Contractor	Cost	Title	City and State
PYRITE-COAL COMBUSTION			
Commercial Testing & Engineering Co.	$66,000	Float-sink testing of coal	Chicago, Ill.
Illinois Geological Survey	75,000	Sampling and evaluation of coal mines in Illinois	Urbana, Ill.
Bituminous Coal Research	158,000	Evaluation of coal cleaning methods and techniques for removal of pyritic sulfur from coal.	Pittsburgh, Pa.
Bechtel Corp. and Stanford Research Institute.	90,000	Process costs and economic study of pyrite-coal utilization.	San Francisco, Calif., Menlo Park, Calif.
Arthur D. Little and Dorr Oliver	60,000	Process cost and market study for pyrite-coal sulfuric acid process.	Cambridge, Mass., Stamford, Conn.
Total	449,000		
Bureau of Mines	40,000	Sink-float sulfur analysis	
Total	489,000		
LIMESTONE-BASED PROCESSES			
Battelle Memorial Institute	180,000	Reaction kinetics of limestone-dolomite with SO_2 in a disperse solid contactor.	Columbus, Ohio.
Babcock & Wilcox Co	173,000	Pilot plant investigations to evaluate potential of direct limestone dolomite injection for control of SO_2.	Alliance, Ohio.
Esso Research & Engineering Co	175,000	Fluidized bed contactor for reaction of SO_2 in flue gas with limestone base materials.	Linden, N.J.
West Virginia University	150,000	Use of pulverized coal fly ash modified by addition of SO_2 removal limestone-dolomite additives.	Morgantown, W. Va.
Pope, Evans & Robbins	210,000	Characterization and control of air pollutants from a fluidized bed combustion unit.	Alexandria, Va.
Total	888,000		
Tennessee Valley Authority	35,000	Effect of limestone-dolomite and derivatives on kinetics of reaction with SO_2.	
Do	55,000	Conceptual design and economic evaluation of process for reduction of SO emissions from power generation.	
Public Health Service (in-house)	140,000	Characterization of reactivity and reaction rate of naturally occurrings of limestone-dolomite with SO_2.	
Total	1,118,000		
ALKALIZED ALUMINA			
AVCO Corp	160,000	Removal of SO_2 from flue gas	Wilmington, Mass.
W. R. Grace & Co. (Davison division)	358,000	Development of improved alkalized alumina for SO_2 control.	Clarksville, Md.
Total	518,000		
Bureau of Mines	200,000	Construction and operation of intermediate scale alkalizing pilot plant.	
Total	718,000		
Contract being developed	255,000	Design of prototype unit for alkalized alumina.	
Total	973,000		

SO_2 control project list—Continued

Contractor	Cost	Title	City and State
MOLTEN CARBONATE			
Atomics International	420,000	Development of molten carbonate process for removal of SO_2 from power plant stack gases.	Canoga Park, Calif.
Total	420,000		
PROJECTS BEING DEVELOPED			
Systems analysis and economic studies.	1,000,000	Systems studies of economic relationships, field studies, and analysis of alternative solutions.	
New Control processes	1,800,000	Stack process investigations and evaluation and work in desulfurization catalysts.	
Control processes—Smelters, refineries, etc.	300,000	Define problems and develop processes for noncombustion sulfur emission sources.	

In-house budget allocations for research and development in air pollution control technology, U.S. Public Health Service and U.S. Bureau of Mines, fiscal years 1957–66

[In thousands of dollars]

	Sulfur dioxide control, R. & D.		Other stationary & source control, R. & D.		Vehicle control		Total	
	PHS	BM	PHS	BM	PHS	BM	PHS	BM
Fiscal year—								
1957	0	32	30	33	60	60	90	125
1958	0	42	40	93	80	92	120	227
1959	0	42	60	87	90	98	150	227
1960	0	45	100	64	90	124	190	233
1961	0	75	130	65	110	160	240	300
1962	50	113	150	50	170	187	370	350
1963	60	120	180	20	220	310	460	450
1964	80	170	180	30	240	300	500	500
1965	150	265	190	46	290	289	630	600
1966	160	270	110	60	340	325	610	655
1967	280	330	150	65	440	389	870	784
Total	780	1,504	1,320	613	2,130	2,334	4,230	4,451

Senator MUSKIE. The other side of the question I asked earlier, Dr. Ludwig: Can you provide the committee with a list of major pollutants for which economical, feasible technology does not exist? Can you supply that for the record? (See previous insert on this day, p. 2274.)

Dr. LUDWIG. This would be probably longer than the other list.

Senator MUSKIE. I suspect so.

Let me ask you this.

Dr. LUDWIG. Would you like me to comment on this a little bit?

Senator MUSKIE. Yes. Would you like to?

Dr. LUDWIG. I think that one of the obvious knotty problems in this regard is the whole area of odor control, whether from pulpmills, rendering plants, and so forth. This is an area that needs considerable R. & D., in my opinion.

Another area concerns gaseous emissions in addition to sulfur oxides for instance, nitrogen oxide emissions. Currently, in considering con-

trol of nitrogen oxide, if such is necessary, from vehicles, we need to take a look at the whole nitrogen oxide control problem from other combustion sources—stationary combustion sources. Another area concerns small industries that have control problems; these are of particular concern because these industries, quite small, could hardly support the R. & D. effort that is needed to develop practical control devices. These are some of the areas.

Senator MUSKIE. Fine. If you could expand on that for the record, especially dealing with the pollutants submitted by the industries which you think are potentially subject to national standards, but any others, too.

Are there any figures to demonstrate the differential cost between installation of pollution control equipment in new plants as opposed to installation of equipment to accomplish a similar result in an existing plant? Do you have any such analysis dealing with any particular industry?

I stipulate that this question is in the testimony by Alcoa last week in which they are putting in new equipment in all new plants where they are locating, but they have the real problem in existing plants.

Dr. LUDWIG. This is generally a recognized problem. For instance, consider vehicular sources. There are drawbacks to putting exhaust control equipment on used vehicles, the fact that there are some 50 or 60 pieces of hardware in the engine that need to be changed to fit a control device into the engine. It is not very easy to go back and remake an engine and put a control device on. I think this extends to stationary source control, too.

In the first place, you may not have the physical area to put a piece of control equipment, the roof is not designed strong enough to hold this massive piece of equipment that may be needed.

I think the second point is that, if you are considering control equipment in a new plant, it can be engineered in with process changes. From this point of view you should be able to come up with a more economical solution by designing control as an integral part of the process than by looking at it as a piece of add-on equipment. You are dealing with essentially one process instead of two, and from this point of view you should be able to deal with it more economically.

Senator MUSKIE. If the gap between the cost for a new plant and the cost for an old plant is too large, how would national emission standards apply in such a situation? Is it conceivable you would have a national emission standard applying only to new plants in a particular industry while you apply answers to the old plants or maybe not to the old plants? What do you envision is the possible policy of that kind of situation? The gap could be very great.

Dr. MIDDLETON. You may wish to have different emission standards for new versus existing plants along the lines, policywise, of changing standards for motor vehicles as improved technology occurs. It seems to me this is a collateral view.

Senator MUSKIE. Well, the difference is that new plants would tend to go into economically viable, new regions. I don't have any one region particularly in mind.

What would this kind of distinction do to the economics of a particular industry to the competitive factors, in a particular industry?

Would it tend to shape the movement of industrial development geographically? Just what would you have to take into account, these factors, regional economics and so on, before you decided to move ahead with the national standards discriminating between old plants and new plants in a particular industry?

Mr. WILLIAMS. I don't think the gap would be great between old and new plants.

Senator MUSKIE. Have you had any orders of magnitude on this, Mr. Williams? It would seem to me when you are dealing with a steel plant, a pulp and paper plant, that the gap could be very great, indeed, but I don't know. I am simply guessing, and it seems to me we ought to have some idea as we contemplate the policy.

I know, for example, that in Maine we have just had a new sugar refinery built in a new area that had never produced sugar beets before. They were able to build into their new plant the control mechanism for water pollution. It looks like that would be 100 percent effective. I take it that the economics are pretty limited, so it seems to me that you cannot dismiss the question with the argument that, well, the gap is not likely to be that great. I think it could be that great and it seems to me we ought to identify the orders of magnitude and think through the policy problems that they pose.

Mr. WILLIAMS. We have thought about some of them at least. I think first we have stressed the fact we are setting minimum standards on those sources for which technology exists. We have been thinking primarily of existing sources. This does not mean that States and local governments might not want to control new sources to a much greater extent than we would consider economically and technically feasible for existing sources. We have been thinking primarily about existing sources, and I would say that there are, I am sure, some facilities which are very marginal even from the viewpoint of the owners.

I know in one of our recent abatement actions affecting several sources, one of the sources was leaking at every possible opening; there were pollutants coming from everywhere, and it was a very old source. Indeed, the abatement action may have stimulated the owner of the source to build a new one or something of this sort. I don't think that everything can remain exactly the same. There are probably some sources which cannot, even with minimal Federal standards, economically apply them, because they are old and they are worn out, so to speak, and they were constructed at a time when pollution control was not considered at all.

Senator MUSKIE. Here is a problem where we can run counter or at least in conflict with some established public policy. The older or nearly obsolescent plants are in less developed, less viable, less dynamic areas. Now, if by developing national standards you tend to make these marginal plants completely unprofitable, the areas that are going to be hardest hit are the areas which have the least potential for stimulating the development of new plants, construction of new plants, or the attraction of new industries.

So, your decision in establishing standards by existing sources, by which I take it you mean older plants, could have the effect of making the richer areas richer and the poorer areas poorer. In the long-

range interests of the country or of the region itself, this may be a good economic result, but it seems to me that if it is, it ought not to be a result arrived at by accident, but that it ought to be part of the policy considerations involved in establishing the standards in the first instance.

Dr. MIDDLETON. I think Dr. Ludwig alluded to this when he talked about the economic tradeoffs and the need to study actually budgeted funds for the involvements of precisely the question you raise. If we have the methodology, but the plant is closed, the economic output of the area is obviously reduced so that the function of the control is not really for its intended purpose. The intention of the emission standard is to provide a minimum standard of air quality which allows the industries to realize the degree to which they must control so that the economic tradeoff can be understood.

I think this is an evolvement from our earlier statements; these and those that Dr. Ludwig suggested would be factors in our determination of emission standards.

Senator MUSKIE. Senator Spong?

Senator SPONG. I am glad you touched on this, Senator Muskie. I have been very much concerned about this entire aspect of the problem because while I can't see this as the major factor, I can see it as a contributing factor in the relocation of industry throughout the United States.

We must bear in mind the tax sources of the localities and the fact that many of these localities are the ones that have the greatest need for tax resources.

Mr. WILLIAMS. It is a very complex problem, indeed. On the other side of the coin, I think these areas that have perhaps the older facilities are often the areas which have the poorest air.

Senator SPONG. This is true.

Mr. WILLIAMS. Are you going to say let the air deteriorate there and keep this old industry there? In addition, I might say that it is not necessarily true that the industries would leave this area where there is a plentiful labor supply and other factors that got them there in the first place.

Senator MUSKIE. I think there are two choices: (1) should we adopt an inflexible national policy, and I use the word "inflexible" not to imply an argument for or against, but simply it is wise to adopt an inflexible national standard which would be applied on a plant-by-plant basis wherever a given industry finds itself located; or (2) is it better to identify the air pollution of the industry and allow the adjustment to be worked out regionally in the areas where the industry creates the problem? I think that is about the choice.

The adjustment process would involve not only adjustment dealing with the problem, but adjustment dealing with the economics of the plant location, industry turnover and whatever you may need to do.

Mr. WILLIAMS. We don't have complete data on it, Senator Muskie, but I don't think the application of air pollution controls in many instances is the determining factor by any means, in plant location.

Senator MUSKIE. Well, if that is the case, then we make progress. I suspect that when it comes to establishing a new industry, this thought you have expressed is more widely applicable than when it

applies to established industry because, if you are undertaking to propose a control on the established industry, the cost may very well knock it out. Again it gets back to the problem.

Well, I raise these questions. We have had a very interesting discussion, and we have gone on for longer than perhaps we should have. But this is very important testimony. I wanted to be sure to try to cover every point that is involved, and I am sure that I have not, but I consider this part of the hearing one of the most important aspects of all our hearings on this bill.

I do appreciate the obvious attention you have given it and the wisdom you have made available to us this morning.

Dr. MIDDLETON. Thank you.

Senator MUSKIE. Now may I say to the other two witnesses that we obviously can't finish this morning, so we are willing to recess, or at least I am, until 1:30 p.m. I can then go on from 1:30 to 3:30. I know you can't control your consumption of time because the committee may get you involved more than you may yourselves choose. Nevertheless, we will try to get the other two witnesses covered from 1:30 until 3:30.

(In answer to previous questions submitted to Dr. John Middleton, Director of the National Center for Air Pollution Control, DHEW, in letters dated March 31 and April 21, 1967, the following answers were subsequently supplied:)

MARCH 31, 1967.

DR. JOHN MIDDLETON,
Director, National Center for Air Pollution Control, Department of Health, Education, and Welfare, Washington, D.C.

DEAR DR. MIDDLETON: As you know, the Subcommittee on Air and Water Pollution is concerned with the present status and projected development of our pollution control and abatement programs. Until recently, our society has labored under the illusion that man, through science and technology, had harnessed the resources of nature and achieved a better life for himself. However, it has become readily apparent that man is but in a state of coexistence with the biosphere.

Concomitant with a technological society and a high standard of living is a high production of pollutants and an increasing need for pollution management. This need is readily apparent when considering atmospheric pollution in the vicinity of urban-industrial complexes throughout our nation. Quoting from Senator Muskie's speech to the National Air Pollution Control Conference on December 13, 1966:

"To date we have set limited goals for ourselves. We have focused on individual pollutants, their weight, their amount, and their immediate and observable effect. We have considered specific emission standards to control individual sources of contamination. We have passed ordinances to reduce smoke; we have planned limitations on sulfur content in fuels used in certain cities; we have taken abatement action against specific polluters.

"These were necessary first steps, but they are not adequate for an effective campaign to improve the quality of our air."

We should by now have developed the experience required to establish national objectives based upon the long term view, emphasizing human goals and values which insure the health and well-being of our society.

Now we must go further—we must attempt to describe the current and projected air pollution levels. We must define the steps necessary to assure the lessening of current levels of pollution and to prevent further environmental deterioration in the future. And recognizing the importance of the economic—technological—environmental relationship we must develop the requisite framework to implement the desired goals.

As an aid to those of us who must provide the legislative framework of the Federal role in air pollution control there are several questions on which a response, from the various programs under your direction, is desirable:

(1) The Center has issued an air quality criteria for oxides of sulfur, the first such criteria called for by the 1963 Clean Air Act. What other criteria are presently under development? What are the anticipated dates of release? What other identified pollutants could ultimately be subject to criteria? There are pollutants which are considered to be generally more dangerous than others, e.g., fluorides. Why have these been ignored?

(2) What are the current and projected efforts to (*a*) study the interaction of pollutants in the atmosphere, (*b*) study the synergistic effect of pollutants on physical and biological systems, and (*c*) to develop an overall ambient air quality criteria which considers the integrated effect on both health and welfare of air pollutants?

(3) To what extent is the Center pursuing development of "national emission standards" as compare with "ambient air quality criteria"? Would the adoption of emission standards, tied to technological and economic feasibility, mitigate the value of air quality criteria related to health and welfare? Because it is proposed that the States have a less than adequate time to adopt standards of their own, would not the effect be adoption of the national standard with little, if any regard for the national ambient air quality criteria? After adoption of minimum emission standards what would be the incentive for the States to move toward meeting an acceptable level of air quality?

(4) What is the anticipated relationship between existing Federal, State and local pollution control agencies and the proposed regional air-shed commissions relative to achieving a national ambient air quality criteria? To setting emission standards?

(5) What efforts have been made to define local air pollution levels which require immediate control actions on a short term basis? Particular attention should be given to emergency situations which seriously impair health or welfare.

(6) To what extent are advisory committees utilized in the establishment of "air quality criteria" or "emission standards"? Would it be desirable to establish permanent advisory committees for these purposes?

(7) To what extent do current and projected air pollution control programs of the Center attempt to direct, or coordinate with, other Federal agencies involved in urban-industrial planning, especially the Housing and Urban Development Department and the Department of Transportation? Particular interest exists in the area of defining the interrelationships of air pollution and the social and economical development of communities in urban areas.

(8) What are current and projected efforts to define the time and space variability of urban pollution levels under various topographic and meteorologic conditions?

(9) In light of projected air control programs, what are anticipated needs through fiscal year 1970 in the areas of (*a*) training and manpower, (*b*) grants for the development of pilot plant facilities, and grants for basic research on (1) control methodology and (2) effects of air pollution?

The above questions will, in most instances, require considerable documentation and careful analysis. It may be, however, that a number of the questions raised, depending on the response, will necessitate legislative consideration. Therefore, we would appreciate your comments no later than May 15th.

Sincerely,

EDMUND S. MUSKIE,
U.S. Senator,
Chairman, Subcommittee on Air and Water Pollution.

JENNINGS RANDOLPH,
U.S. Senator,
Chairman, Committee on Public Works.

MARCH 31 LETTER

Question 1. The Center has issued air quality criteria for oxides of sulfur, the first such criteria called for by the 1963 Clean Air Act. What other criteria are presently under development? What are the anticipated dates of release? What other identified pollutants could ultimately be subject to criteria? There are pollutants which are considered to be generally more dangerous than others, e.g., fluorides. Why have these been ignored?

Answer. Air quality criteria for several other major categories of pollutants have been under development for some time. Among them are criteria for photo-

chemical oxidants, nitrogen oxides, and hydrocarbons. Closest to completion are the criteria for photochemical oxidants. A draft of this document is undergoing detailed review and is being supplemented with additional material. It is expected to be completed October 1967. Criteria for nitrogen oxides, hydrocarbons, and carbon monoxide should be completed early in 1968. Work is also under way on the development of criteria for particulate pollutants. The initial document on particulate matter will be focused primarily on the overall mixture of particulates present in polluted urban air, though some attention will be given to various components of the mixture. Work on this document is scheduled for completion by the fall of 1967. Additional documents dealing in greater depth with the most important types of substances generally present in particulate matter will be prepared afterward.

Other pollutants for which the development of criteria is under consideration include lead, fluorides, hydrogen sulfide, certain heavy metals, ethylene, asbestos, organic carcinogens, and aldehydes. The development of criteria for odors is also being considered. The sequence in which these additional criteria will be developed will depend in large part on an evaluation of the relative urgency of making such criteria available for the various categories of pollutants.

Priorities for the development of criteria for various categories of pollutants have been, and will continue to be, determined on the basis of several considerations, including the magnitude and seriousness of the problems associated with each category of pollutants, the extent and seriousness of their effects on health and welfare, and the degree of the need for such criteria in connection with air pollution prevention and abatement activities. On the basis of such considerations, first priority has been assigned to the development of criteria for the most widespread and common types of pollutants—sulfur oxides, photochemical oxidants, carbon monoxide, hydrocarbons, nitrogen oxides, and particulate matter.

Question 2. What are the current and projected efforts to (*a*) study the interaction of pollutants in the atmosphere, (*b*) study the synergistic effect of pollutants on physical and biological systems, and (*c*) to develop an overall ambient air quality criteria which considers the integrated effect on both health and welfare of air pollutants?

A. (*a*) The association of atmospheric reactions initiated by sunlight and oxidant formation—rubber cracking, plant damage, aerosol formation, and eye irritation provided the incentive for a large number of photochemical investigations. The earlier studies demonstrated that automobile exhaust when irradiated after dilution to atmospheric concentrations would produce oxidant, aldehydes, peroxyacyl nitrates, plant damage, eye irritation, and aerosols. It also was shown that individual hydrocarbons, particularly olefins, when irradiated with nitrogen oxides in air would cause most of the same effects. If sulfur dioxide also was included with an irradiated mixture in air, much greater aerosol formation occurred. Work also was done in the reaction of olefins with ozone and atomic oxygen. This appeared to contribute significantly to the overall rates of reaction of the olefins and to subsequent yields of various products.

Work in photochemical reactions in Federal laboratories has been done by the Public Health Service, by the Bureau of Mines, and by the Bureau of Standards. The work at the Bureau of Standards has been concerned with basic photochemical mechanisms. Considerable basic photochemical work has also been stimulated in universities through the PHS research grant program.

The Public Health studies have been conducted both in large irradiation chambers and in small laboratory-scale apparatus, including long-path infrared equipment. The large irradiation chambers are essential if eye irritation, plant damage, or animal studies are to be made, since very large volumes of irradiation products are needed. Measurements have been made with the large chambers under dynamic flow conditions rather than the static conditions used by other investigators. Use of dynamic conditions permits a better approximation to atmospheric changing by pollutants than do static chamber conditions.

One significant study in these large chambers involved the irradiation of automobile exhaust mixtures, with careful control of hydrocarbon ad nitrogen oxide concentrations and their ratios. It was possible to relate aldehyde, oxidant, plant damage, and eye irritation to reactant concentration and ratio.

A more recent dynamic irradiation study in the large-chamber facility involved a survey of the relative chemical and biological reactivities of paraffinic hydrocarbons, olefins, aromatic hydrocarbons, aldehydes, and mixtures of hydro-

carbons. Such a survey-type study had not been made before under dynamic conditions.

The overall results obtained in the Public Health Service laboratories provided essential data on the effects of hydrocarbon and nitrogen oxide concentrations on atmospheric reactions. The significant role of aromatic hydrocarbons and aldehydes in atmospheric reactions was made clear by these studies. Various of these investigations have indicated that the reactions of atomic oxygen and ozone with various types of hydrocarbons and aldehydes account for only a small part of the reactivity of these systems.

Photochemical studies by the Bureau of Mines are concerned with the chemical reactions involved in irradiated systems and the analytical developments needed to better study these systems. Considerable work has been initiated on the role of oxygenated substances, particularly aldehydes, in irradiations with nitrogen oxides. Work also is in progress on various analytical and instrumental techniques to measure reactivity chemically to develop improved instrumentation for reactive substances in automobile exhaust.

The work at the Bureau of Standards is concerned with the basic mechanisms involved in photochemical reactions. Such work involves study of the formation of various radical species, transitions between energy states, and quantum yield measurements. Recently work has been started on the photooxidation of polycyclic hydrocarbons. A number of photochemical investigations are sponsored in universities with research grant or contract funds. In one of these, considerable work has been done on damage to various plant species by irradiated hydrocarbon-nitrogen oxide mixtures and olefin-ozone mixtures. More fundamental work on the effets of pollutants on biochemical systems in plants also is in progress. Basic photochemical work has emphasized a detailed study of the photolysis of nitrogen oxides and photooxidation of various aldehydes and ketones. Studies of the reaction of alkyl radicals with oxygen and photosensitized surface reactions have been conducted. Basic work on the physics of photochemical aerosol formation is in progress. The effect of pressure, temperature, and humidity on oxidant formation in the irradiated olefin-nitrogen oxide system has been studied. The photooxidation of alkyl iodide was investigated. Other less extensive studies or more recently initiated projects are in progress at several universities.

In the period between 1950 and 1960 much of the research in photochemistry was supported by non-Federal sources. A large program of investigation in a large irradiation chamber was conducted for several years at the Stanford Research Institute Laboratories in Pasadena. This work included chemical, aerosol, and eye irritation measurements. A large irradiation chamber was constructed by the Los Angeles Air Pollution Control District. Over the years LAAPCD did considerable irradiation work on automobile exhaust, particularly in an effort to study the influence of fuel composition on the effects of irradiated automobile exhaust. The District's facilities are now being used by the California State Department of Health as part of its auto exhaust program.

In more recent years the General Motors Corporation Research Laboratories have reported several investigations done in a long-path infrared apparatus. Investigators at California Research Corporation also have completed several photochemical investigations. In one of these studies C^{14} tracer techniques were used to follow formaldehyde yields in the irradiate ethylene-nitric oxide system and in the presence of various added organic substances. This same group recently has made a laboratory study of the role of sulfur dioxide in visibility reduction. An investigation of the effect of various parameters on the production of aerosols by the irradiation of the 2-pentene-nitric oxides system was sponsored by the American Petroleum Institute.

Two of the general problems involved in doing photochemical work in atmospheric type systems are the quantitative reliability of results and the reliability of extrapolations of results from higher concentration levels. Despite a number of studies, the amount of quantitative data on all important aspects of various individual systems is limited. For example, peroxyacycl nitrate measurements are available for a number of systems, but oxidant data often were not obtained. While significant amounts of data are available for aldehyde and ketone yields from the irradiation of olefin-nitrogen oxide systems, the yields reported in different studies often vary considerably. While these variations could easily result from light intensity and temperature differences in the various investigations, not enough experimental data on these parameters are available to make adequate corrections.

More reliable quantitative data certainly are needed on product yields over a wide range of reactant concentrations, light intensities, and temperatures. Not only can doubts be expressed about the extent and quantitative reliability of yield data, but also about the experimental conditions use to obtain them. It is not necessarily true that the behavior of an irradiated system at 10 ppm each of the reactants will be the same as at 0.25 ppm of reactants. Yet the lower concentrations cited are much more representative of actual atmospheric concentrations. The systems being studied are much too complex to be explained in terms of simple binocular reactions. It also is not sufficient to limit measurements to those made during the earliest stages of the reaction, when secondary reactions are of smaller consequence.

With these limitations, it is difficult to be sure of the applicability of results as they apply to atmospheric conditions when extrapolations of one or two orders of magnitude are required. On the other hand, experimental work at concentration levels below one part per million are beset with difficulties arising from analytical limitations, surface effects, and contamination sources (gaskets, seals, etc.). Despite these problems, serious consideration should be given in all future investigations to the inclusion of realistic atmospheric concentrations within the experimental design used.

Relatively few detailed data are available on the chemical or biological aspects of reactions which involve aromatic hydrocarbons and aldehydes. An understanding is lacking of all but the grossest aspects of the mechanism by which most organic species participate in photooxidation reactions. In fact, it is even impossible to account for the overall rates observed on the basis of ozone or atomic oxygen reactions. Free radical reactions have been postulated as important, but quantitative date on the rates of free radicalorganic substance reactions are not available. The types of free radical species present have not even been positively identified. This entire area involving the role of free radical reactions in atmospheric chemistry needs a great deal of effort.

The mechanism involved in the formation of photochemically produced aerosols is obscure. Sulfuric acid aerosol has been identified as the only important substance in the aerosol from the photooxidation of olefin-nitrogen dioxide-sulfur dioxide. However, considerable organic material has been reported in atmospheric and automobile exhaust aerosols. Also, sulfuric acid obviously cannot be present when aerosol is formed from the irradiation of the higher molecular weight olefins and aromatic hydrocarbons with nitrogen oxides. Such considerations raise many questions about the importance of sulfur dioxide in visibility reduction.

In making practical judgments about the relative contribution of classes of compounds, subclasses, or individual compounds, abundant chemical and biological indicator data are essential. These measurements are needed in order to establish more detailed control standards for hydrocarbons based on reactivity. Yet we have numerous gaps in our data on aerosols, eye irritation, and plant damage. We particularly lack meaningful data at realistic atmospheric concentrations. It is disturbing that it is so difficult to obtain significant eye irritaton, plant damage, and aerosol levels even in laboratory irradiations using atmospheric concentrations of reactants. More sensitive techniques, particularly techniques with better reproducibilities, are badly needed in the future. However, use of present techniques for eye irritation and plant damage in conjunction with carefully controlled chamber irradiations and detailed chemical analyses can continue to supply needed and useful data.

Data on eye irritation and plants as biological indicators also are needed as a function of nitrogen oxide concentration at low hydrocarbon and nitrogen oxide levels. Again, the previously discussed limitations cause problems. However, sound judgments on the need for nitrogen oxide control standards require such data in the near future.

Appropriate chemical conditions appear to be necessary in order to cause photochemical air pollution but these alone are not enough; meteorological conditions too must be sufficiently adverse. In attempts to reproduce the atmosphere in the laboratory, meteorological conditions are grossly oversimplified. In great part, this oversimplification reflects a lack of data on micrometeorological conditions before and during the photochemical air pollution situations. The techniques available to trace the movement of air masses are inadequate. Work is in progress on the development of sensitive chemical tracer substances. The use of such substances eventually should permit meteorologists to trace the move-

77-515 O—67—pt. 4——8

ments of polluted air masses in considerable detail. The ultimate goal should be an integrated chemical and meteorological model of atmospheres undergoing photochemical and secondary reactions which has useful predictive value for the areas suffering from this type of air pollution.

To understand the processes by which air pollutants exort an influence on organisms and materials requires knowledge not only of the concentrations of pollutants but also of the physical and chemical forms of the pollutants and their modification in the atmosphere. With more certain knowledge of the effects of combinations of primary pollutants under varying atmospheric conditions, a firm foundation will exist for the control of certain pollutants; it is also possible that atmospheric reactions can render certain combinations of primary pollutants less harmful as well as more harmful. With greater knowledge of the forms into which primary pollutants are changed by physical and chemical processes in the atmosphere, the ultimate fate of these pollutants can be more readily determined.

Research to investigate atmospheric reactions is complicated by two facts: (1) in most cases, only trace quantities are involved, and reactions that take place may differ considerably from those that take place in bulk quantities; and (2) in the real atmosphere, there can be unsuspected interferring trace substances present. It also appears that many trace substances, whatever their bulk properties may be, are found in the atmosphere either adhering to small particles, or in the form of nebulous particles of varying cohesiveness.

Work currently under way can be grouped in two principal categories: air chemistry, and removal processes. In the field of air chemistry, the greatest effort is directed toward learning about the atmospheric reactions among the primary pollutants emitted by automobiles, especially as these reactions are influenced by sunlight. Some work is being undertaken on pollution of the atmosphere by sulfur compounds, and the conversion of these compounds from the gaseous to the liquid or solid state, adsorption on surfaces of particulates, etc. Work on removal processes is directed primarily toward describing effects, with inferences drawn as to the process responsible. There is some overlap between dispersion studies and studies of removal. For instance, rainout of nuclear debris is a function of the dispersion of the debris fully as much as the mechanics of formation of precipitation elements; and studies of dry deposition are carried out primarily by carefully designed small-scale diffusion studies.

There is much yet to be learned concerning atmospheric reactions. There is a vast amount of work that could profitably be done to quantify known reactions and, as analytical methods for the identification of additional trace substances continue to develop, more reactions will need to be catalogued. In particular, improved emission data from source surveys should be used as guidance to determine those atmospheric mixtures that are likely to exist, and potential reactions among such mixtures can be investigated. Reactions should be studied over the complete range of atmospheric conditions that are likely to be found, including the varying ambient states that the atmosphere normally undergoes.

The physical states of pollutants, and the processes of particle formation and growth, are poorly understood. For instance, submicron sized particles act as the principal condensation nuclei for cloud or fog droplet formation, but the role of cyclic condensation and evaporation of water on the formation and growth of atmospheric aerosols has not been studies. The process of collection of aerosols may alter their pyhsical form, and it would be highly desirable to develop techniques for the study of particles as they exist in suspension in the air. Complete knowledge of the physical form in which pollutants exist would aid in describing the types and rates of chemical reactions that take place. The roles played by radiation, electrostatic forces, humidity, and other physical variables in atmospheric reactions, need clarification. For all forms of pollutants, further studies of dry deposition are needed; it appears that turbulent impaction is a principal means of deposition of "large" particulates; as the particle size is reduced, ultimately to molecular dimensions, other means, such as chemical affinity, or thermal diffusion, must play an increasingly important role. These processes need much more detailed study to put deposition studies on a firm physical foundation, and thus eliminate the present need for case-by-case empirical studies.

Studies of atmospheric composition on a global scale, and derivation of the effects of pollutant emissions on the long-period trends of atmospheric composition, are seriously hampered by the present lack of adequate measurement programs. Improved knowledge of global dispersion, and the relationships between high and low atmosphere processes, must depend on adequate measurements.

Because of their worldwide nature, studies of global exchange rates, changes in atmospheric composition, and the effects of high altitude phenomena, can

properly be carried out only on an international basis. Determining the basis for the rising trend of atmospheric CO_2, for instance, requires precise knowledge of all the sources and sinks for CO_2. These include not only the emissions of CO_2 by the burning of fossil fuels, but also the consumption and emission of CO_2 by vegetation, live and decaying, the possible binding of CO_2 in weathering rock, and particularly the regional CO_2 exchange between the oceans and the atmosphere. The further question of whether the rising trend of CO_2 is a cause of a general warming of the atmosphere cannot be answered by simply examining trends, but must be interpreted in terms of the total energy balance of the atmosphere, which in turn requires much more detailed measurements of the variations of incoming solar energy and outgoing longwave radiation from the earth than have been available except with the aid in recent years of satellites and high-level rockets. While there must be a continuing concern that we might be introducing deleterious changes in climate by our pollution-producing activities, the requisite measurements are not presently available, and thus the primary effort in studying global-scale phenomena should be the encouragement of more definitive sampling.

(*b*) Four types of interactions among pollutants are of importance with respect to synergistic effects: (1) Potentiation of irritant effects by non-irritants. This has been amply documented by research regarding sulfur dioxide and an inert aerosol, sodium chloride. The conclusion was that particulate matter, which, in itself, may have no demonstrable effect on airway resistance, does enhance the effect of simultaneously inhaled sulfur dioxide; (2) A change in the qualitative nature of the effect. With regard to pulmonary function values, one irritant gas by itself will cause an increase in respiratory flow resistance and a concomitant decrease in respiratory frequency response. The addition of another gas will change the frequency response but not the resistance response. This has been illustrated by studies of acrolein alone and acrolein plus ozone; (3) A reduction in the potency of an irritant because of antagonism by one or more other agents. A preliminary study of the effect of atmospheric mixtures of nitrogen dioxide and carbon monoxide among emphysematous rats (the emphysema being caused by nitrogen dioxide) has suggested that these rats had a higher tolerance to carbon monoxide than did normal rats; and (4) An additive effect. Thus, the cocarcinogenicity of nickel carbonyl and benzo(a)pyrene may simply mean the hitting of different target sites.

Also of importance in defining the synergistic effects of air pollutants are interactions of pollutants and disease factors, such as micro-organisms. Evidence is at hand, for example, regarding the potentiation of influenza virus when accompanying an insult by a contaminant. A final area of importance is the interaction of pollutants with chemical or physical stress. Experimental data demonstrate that endocrine imbalance in animals causes a marked alteration in the animal's susceptibility to ozone.

The National Center for Air Pollution Control is currently conducting or planning to begin, during the next fiscal year, a number of projects concerning the synergistic effects of pollutants, as defined above. These projects include:

1. An in-house study in chambers of long-term, low-level exposure of several species of animals to several single and combined pollutants will be continued. This study was begun in September 1965. The exposures of interest involve sulfur dioxide plus a sulfuric acid aerosol and this combination of pollutants with raw and irradiated auto exhaust.

2. Contractors will study behavioral, biochemical, fine structure, physiological, and pathological findings in dogs related to known exposures to single and combined pollutants. These cover sulfur dioxide, ozone, nitric oxide, nitrogen dioxide, carbon monoxide, and ambient Los Angeles smog. Previous work by these contractors had covered the effect only of ambient atmospheres. Effects of these single and mixed pollutants will also be studied on a group of psychologically stressed and adrenalectomized animals. Fine structural studies of pulmonary tissues will be made for young, old, and exercised animals following short, periodic, and continuous exposures.

3. An in-house study will be continued which is designed to determine the effect on respiratory physiology of low levels of ozone and nitrogen dioxide, separately and combined. The animals exposed to air pollutants will also receive a respiratory stress via treadmill exercise or carbon dioxide inhalation.

4. Another in-house activity involving interplay between pollutants will be continued. This involves the experimental exposure of laboratory animals to selected gaseous and particulate pollutants singly and in combination. The pol-

lutants are nitrogen dioxide, nitrogen dioxide plus a ferrous oxide aerosol, and ferrous oxide alone. Also to be studied are sulfur dioxide, sulfur dioxide plus a sulfuric acid aerosol, and sulfuric acid alone. The effects to be looked at are hematologic, cardio-respiratory physiology, biochemical, including enzymes and ion shifts, and gross and microscopic structural changes. There is also to be some emphasis on stress-response sub-projects.

5. A continuing in-house activity will be supplemented by a contract to study the effects of air pollutant exposures upon central nervous system related functions in primates and man. The pollutants to be studied include carbon monoxide, ozone, lead, automobile exhaust and selected components and combinations. The methods of measurement include polygraph, olfactometry, discriminant function, neurochemical and other pertinent techniques.

6. Contract and in-house work will be continued on investigating the effects of air pollutants alone and in combination with other agents in the causation of infectious, neoplastic, and structural diseases of the lung. The effect of combined treatment with ozone and nitrogen dioxide and of sulfur dioxide and particulates on alterations of susceptibility to pulmonary infectious disease will be investigated on animals. The influence of inert particulates as a carrier agent for carcinogens and the effect of airborn carcinogens will be studied by inhalation experiments.

7. An experimental epidemiologic study of the effect of sulfur dioxide on naturally transmitted influenza virus infection in mice will be initiated by a contractor. This will permit a better understanding of the interaction of air pollution and respiratory infection.

8. Systematic epidemiologic studies of daily deaths in Philadelphia (in-house) and New York (by contract) will be continued, with particular attention to the combined and separate influences of air pollutants and meteorological factors, particularly extremes of temperature. It is possible that influenza epidemics may also be identified and taken into account.

9. Contract studies on the effects of oxidants on athletic and other human performance will be enlarged at Los Angeles in an effort to discover the mechanism through which ozone and other photochemical oxidants affect the human system.

10. A program of basic physical and chemical interaction studies on an in-house and contract basis is to be continued. In addition to establishing and monitoring concentrations and physical and chemical characteristics of pollutant components in the animal exposure atmospheres, analytical techniques are being developed to more adequately characterize the exposure components during the complete exposure period. This supporting activity is vitally necessary to the development of sound research.

(*c*) The air quality criteria published for sulfur oxides pollution pertain not only to effects on health but also to effects on vegetation, materials, and visibility. Future criteria will also be concerned with both health and welfare.

As for the development of criteria reflecting the effects of the overall mixture of pollutants present in the atmosphere, progress in this direction can be expected. The fact is that the effects of the total burden of air pollution and of various combinations of pollutants must inevitably be considered in the development of criteria, if the criteria are to be a useful guide to the establishment of a quality and emission standard. In the development of the criteria for sulfur oxides, for example, some of the data taken into consideration came from investigations of the effects of air pollution totally and of combinations of sulfur oxides and other pollutants. Future criteria will reflect similar considerations, whenever appropriate.

As additional and more detailed data become available on the impact of various combinations of pollutants, it is anticipated that criteria can be prepared which will reflect such knowledge and thus provide an improved basis for determining the degree of control of air pollution necessary for complete protection of public health and welfare. Such criteria might take two forms: (1) Criteria reflecting knowledge of the adverse effects of various combinations of pollutants, showing the influence of variations in the ratio of pollutants and in the ambient air levels of such combinations. (2) Air quality criteria expressed in terms of index measurements of one member of a group of pollutants.

In any event, since an effective attack on air pollution must include measures for the control of specific pollutants from specific sources, criteria for individual categories of pollutants (and possibly for combinations of two or more pollutants arising from the same source) will continue to be the most logical, most appro-

priate, and most realistic guides to needed air pollution prevention and abatement efforts.

Question 3. To what extent is the Center pursuing the development of "national emission standards" as compared with "ambient air quality criteria?" Would the adoption of emission standards, tied to technological and economic feasibility, mitigate the value of air quality criteria related to health and welfare? Because it is proposed that the States have a less than adequate time to adopt standards of their own, would not the effect be adoption of the national standard with little if any, regard for the national ambient air quality criteria? After adoption of minimum emission standards, what would be the incentive for the States to move toward meeting an acceptable level of air quality?

Answer. The Department of Health, Education, and Welfare has a specific mandate, under the Clean Air Act, for the development of ambient air quality criteria; accordingly, the National Center for Air Pollution Control has assigned several members of its technical staff to devote essentially their entire time to the development of such criteria. There is, of course, a close connection between criteria and standards, and for this reason, a single Associate Director of the National Center has been assigned responsibility for the development of ambient air quality criteria, as called for by the Clean Air Act, and for the development of those standards called for by the existing legislation as well as any which may be required under future legislation.

Existing legislation authorizes standard-setting with respect to motor vehicle pollution and pollution arising from Federal installations. There is no existing authority for the development of national emission standards for other sources of air pollution. For this reason, the National Center for Air Pollution Control is not currently carrying on activities pointed specifically toward the development of national emission standards, as envisioned in the proposed Air Quality Act of 1967.

In many respects, however, most of the current and past activities of the air pollution program—including research and development, abatement, and technical assistance to State and local agencies—represent a source of the data that will be needed for the development of emission standards. Of particular relevance are the many studies that have been or are now being made of air pollution problems associated with specific industries and of the measures available for dealing with those problems; most such studies have been made in collaboration with industry groups. Among the industries covered by such studies are iron and steel, kraft pulping, petroleum refining, and sulfuric acid and nitric acid manufacturing.

The promulgation of national emission standards for major industrial sources would in no way mitigate the value of air quality criteria or the ability of State and local governments to achieve air quality consistent with such criteria. On the contrary, promulgation of national emission standards would enhance the ability of State and local agencies to carry on effective air pollution control programs. For most types of pollutants discharged from industrial facilities, compliance with the national standards would require application of all economically and technically feasible control methods now available. Thus, adoption and enforcement of the standards at State and local levels would expedite progress toward an objective already set by many State and local governments—the objective of achieving full use of the existing technical capability for prevention and control of air pollution problems.

In those instances—and there probably will be few—in which particularly rigorous control of air pollution is necessary, because of such factors as chronically poor atmospheric ventilation or the character of a particular area, e.g., a resort, the setting of national standards would in no way lessen the incentive for State and local governments to take additional measures, such as relocation of pollution producing facilities, requiring materials and process changes that would reduce pollutant emissions, or requiring the use of more effective control equipment than is necessary to meet the national standards, provided such equipment is available. And finally, in all States and communities, the setting of national standards for major industrial sources of air pollution would not only lessen discharges of pollution from such sources, but would give State and local agencies an improved opportunity to deal with the many other types of pollution sources located within their jurisdiction, including such sources as burning dumps; residential, commercial, and municipal incinerator; and a variety of small manufacturing and processing operations.

Question 4. What is the anticipated relationship between existing Federal, State, and local pollution control agencies and the proposed regional and air-

shed commissions relative to achieving a national ambient air quality criteria? To setting emission standards?

Answer. With respect to achieving air quality consistent with air quality criteria published by the Department of Health, Education, and Welfare, regional air quality commissions would be expected to use the criteria as guidelines in the development of air quality standards, just as State and local agencies are expected to use them.

With respect to setting emission standards, the national standards would represent minimum requirements for the control of major industrial sources of air pollution. State and local agencies would be required to adopt equivalent or more stringent standards, where necessary for the protection of public health and welfare and where economically and technically feasible control technology is available. Regional air quality commission would have the same function, insofar as standard-setting is concerned, in the areas under their jurisdiction.

Question 5. What efforts have been made to define local air pollution levels which require immediate control actions on a short-term basis? Particular attention should be given to emergency situations which seriously impair health or welfare.

Answer. Scientific data on the ambient air pollution levels that can be expected to produce acute illness and/or death are available from epidemiological, clinical, and laboratory research on the effects of air pollution. Knowledge of the acute effects of sulfur oxides is reflected in the published criteria for this class of pollutants. Criteria for other pollutants will contain similar information, insofar as it is available. Though much remains to be learned about this important aspect of the air pollution problem, sufficient data are already available to permit, with respect to some pollutants, determination of the ambient air levels at which emergency control action should be taken. The National Center for Air Pollution Control has provided information and advice on this subject to State and local agencies that have requested assistance. Additional information on this subject is included in the response to question 7 of the April 21 letter to Dr. Middleton.

Question 6. To what extent are advisory committees utilized in the establishment of "air quality criteria" or "emission standards?" Would it be desirable to establish permanent advisory committees for these purposes?

Answer. In the development of air quality criteria, the advice of non-Federal experts is obtained in two principal ways. The first is by the appointment of committees of scientists who, because of their own experience, are particularly well informed on the adverse effects of the pollutants for which criteria are being developed. These committees help insure that all pertinent research is considered, that valid interpretations of the research are made, and that the language used in the criteria documents is accurate and understandable. Each such committee serves only during the development of a single set of criteria and is then disbanded. The second principal way in which advice on the development of criteria is obtained is through consultation with representatives of commercial and industrial interests that may be affected by control measures based on criteria published by the Department. No formal committees have been established for this purpose. Instead, groups known to be interested are advised of the work in progress and asked for comment. In many instances, meetings are held with representatives of interested groups. Unsolicited comments from interested parties may also be considered. It is important to recognize that since air quality criteria must, in accordance with the Clean Air Act, reflect available scientific evidence of the effects of air pollution, consideration is given only to those comments bearing on the accuracy and validity of such scientific evidence and on the validity of the evaluations made in the development of criteria. Though comments on economic, technological, and other factors are often submitted and are given appropriate attention, they cannot be taken into consideration in the development of criteria.

The Department currently has responsibility for setting national emission standards for only one group of air pollution sources—motor vehicles. The procedure being followed in setting motor vehicle standards includes extensive communication and consultation with the affected industries. This procedure includes publication of proposed standards, receipt and consideration of comments from interested parties, and, in many instances, discussions with representatives of affected industries—all before the standards are officially promulgated. A similar procedure would be employed in the development of national emission standards for other major sources of air pollution. This approach is clearly preferable to the creation of permanent advisory groups, whose members are seldom, if ever,

authorized to speak for an entire industry or even individual companies, except with respect to strictly technical matters. The creation of such groups would not relieve the Department of its obligation, as a public agency, to give public notice of its intention to establish any new rules or standards and to give all interested parties an opportunity to submit their comments.

Question 7. To what extent do current and projected air pollution control programs of the Center attempt to direct, or coordinate with, other Federal agencies involved in urban-industrial planning, especially Housing and Urban Development and Department of Transportation? Particular interest exists in the area of defining the interrelationships of air pollution and the social and economic development of communities in urban areas.

Answer. The Department of Housing and Urban Development shares a mutual interest in air pollution control with the Public Health Service, because such pollution is both a cause of urban blight and deterioration and an effect of the various facets of urban development. This mutuality of interest has been the basis for discussions directed toward cooperative efforts between the two agencies seeking (1) to develop a recognition of this interrelationship by State and local community leaders and planning agencies, (2) to encourage communities to consider this interrelationship explicitly in their planning activities and in their community development program operations, and (3) to formulate policies and procedures within the two Federal agencies, particularly with respect to financial aids and technical assistance, to foster the accomplishment of the preceding two objectives.

The purpose of the Urban Planning Assistance Grants administered by the DHUD is to provide assistance for comprehensive planning for entire urban areas. Studies of air pollution are considered important as factors in sound comprehensive urban planning. The first joint effort in this regard came before the passage of the Clean Air Act and before the establishment of the DHUD. The Public Health Service worked with the Housing and Home Finance Administration, a predecessor of the DHUD, concerning a study of pollution in the Chicago metropolitan area, which was conducted by the regional planning commission and the State and local air pollution agencies and financed in part by an urban planning assistance grant. The Public Health Service provided the staff for this project and the funds for contract work.

The National Center for Air Pollution Control and the DHUD have established policies which give the Center the major responsibility for the funding of air pollution control activities undertaken as an element of comprehensive planning. Currently the Center has made seven grants for projects of this type.

Representatives of the Center and the DHUD have had fruitful discussions on a series of matters leading to the development of incinerator standards for Federally-financed public housing.

Under the Urban Mass Transit Act of 1964, administered by the DHUD, new mass transit vehicles purchased with Federal funds must meet air pollution control specifications established by the Secretary of HEW. The two departments have been in regular contact to develop and apply such specifications.

In other areas, representatives of the Center are also meeting with DHUD officials to explore the development of air pollution standards to be applied in HUD's planning and development grant programs and to discuss such other matters as urban transportation planning and open space planning.

The Center is currently working with the Department of Transportation on procedures for enforcing the motor vehicle emission standards which become effective on all 1968 and later model automobiles. The Center has established liaison with the Department of Transportation to work on other problems of mutual interest. Since that Department has only recently been established, however, arrangements for coordination have not been completed, as yet.

The Center also maintains liaison with several other Federal departments and agencies whose activities in the urban-industrial planning field have a bearing on air pollution problems. Among these are the Department of Commerce, the Federal Power Commission, and the Department of the Interior.

Question 8. What are the current and projected efforts to define the time and space variability of urban pollution levels under various topographic and meterologic conditions?

Answer. Essentially all of the air pollution measuring and monitoring activities of the Federal air pollution programs during the past ten years have been directed toward gathering information on this question. These activities have provided some air quality data on essentially all cities over 100,000 in population, approxi-

mately half of the cities of 50,000 to 100,000 population, and a sampling of cities of below 50,000 population. This information is routinely published by the National Center for Air Pollution Control; the most recent of such publications is "Air Quality Data from the National Air Sampling Networks and Contributing State and Local Networks, 1964–1965."

Special studies conducted in places such as Louisville, Nashville, St. Louis, and Charleston, W. Va., have provided information on the spatial variability of urban pollution in single urban areas. In general, such studies have indicated that the avergae spatial variation of pollution in a given urban area has a relatively limited range. For example, the ratio of average suspended particulates in a center city to the average in suburbs generally falls in a range of approximately 1.7 to 2.5. The ratio for a gas such as sulfur dioxide generally falls in a range of three to five.

The air quality information gathered thus far has allowed considerable definition of diurnal, daily, seasonal, and annual variations in air pollution levels. These trends have been documented in numerous technical papers and individual publications, one example of which is "The Trend of Suspended Particulates in Urban Air 1957–1964."

The information collected over the last ten years is proving increasingly useful in assessing the geographic distribution of types of air pollution across the country, with particular reference to common parameters of community activity which relate to air pollutant emissions. Studies now in progress include efforts to define the relationship of ambient air levels of sulfur dioxide, sulfates, and vanadium to total emissions of sulfur dioxide and types of fuels burned in major urban areas and the relationship of ambient lead and iron levels, respectively, to annual gasoline sales and the presence of substantial steel-producing operations.

The National Center for Air Pollution Control has recently published the results of two projects aimed at classifying the relative severity of pollution problems in American communities. In the publication, "Air Pollution, A National Sample," issued in December 1966, some 300 communities were listed by State, with respect to the relative concentration of 15 pollutants. Even more recently, the National Center published a list indicating the 20 major industrial standard metropolitan statistical areas having the most severe, general, interrelated suspended particulate-sulfur oxides pollution problems.

A substantial amount of laboratory effort over the last two years has been directed toward the development of improved sampling and laboratory techniques to facilitate the definition of both time and space variability of pollution and the association of these trends with causative factors. For example, methods of analyzing samples of particulate matter to determine their content of metals have been improved to provide a five-fold increase in sensitivity. This increase in sensitivity has allowed the recent completion of a survey of background levels of some 17 metals of biological importance at 33 rural air sampling stations. Even more importantly, it is being used to provide current metals information on more communities, and, through analysis of available air samples from previous years, to determine the trends of metals over the last ten years. In some special cases, such as beryllium, there has been an even greater improvement in the sensitivity of analysis, so that communities have periodic, detectable concentrations of beryllium can be more clearly identified.

By July 1967, as a result of improved techniques for the detection of benzo-a-pyrene, the National Center will be in a position to report on variations in levels of this pollutant in more than a hundred communities.

The procedure used to analyze air samples for the presence of fluorides has been improved to provide a ten-fold increase in sensitivity and is now being employed in routine examination of all particulate samples. This will permit detection of fluoride concentrations at least as low as 0.1 micrograms per cubic meter. At selected sampling stations, routine 24-hour sampling for gases has been expanded to include ammonia, aldehydes, and total oxidant, in addition to sulfur dioxide and nitrogen dioxide. By July 1967, methane analyzers will be installed at the six continuous air monitoring stations. This will allow a more realistic determination of varations in levels of those hydrocarbons most prone to participate in photochemical reactions.

In the coming Fiscal Year, periodic sampling for gaseous and particulate pollutants will be expanded to provide more definitive coverage of the major standard metropolitan statistical areas. In a limited number of places, this sampling will be conducted at multiple sites to provide better information on the outward spread of high pollution levels around urban core areas over an extended period

of years. Such information is a needed amplification of the long-time trends of pollutant concentrations in the more heavily polluted core areas. Initial studies of this type are presently underway in the Philadelphia, Chicago, and Gary-Hammond-East Chicago areas. In Fiscal 1968, the National Center will begin to accept multiple-site information on air quality from communities that have developed such information independently of the Federal air sampling networks. Thus, increasingly in the near future, the Center will be in a better position to make use of air quality data generated not only through its own efforts but also through those of State and local agencies.

Question 9. In light of projected air control programs, what are anticipated needs through Fiscal Year 1970 in the areas of (*a*) training and manpower, (*b*) grants for the development of pilot plant facilities, and grants for basic research on (1) control methodology and (2) effects of air pollution?

Answer. (*a*) With respect to training and manpower, it is estimated that, in 1966, State and local air pollution control agencies' budgets included provision for 2,200 to 2,500 staff members, but since many positions were vacant and many staff members were devoting only part of their time to air pollution work, the actual number on duty was substantially smaller. The estimate is that State and local agencies actually employed the equivalent of some 1,800 full-time personnel.

If the funds requested for Federal grants to local, State, and regional agencies in Fiscal Year 1968 are made available, and if these are matched by grantees in accordance with the requirements of the Clean Air Act, total budgeting by such agencies would rise by approximately 35 percent. If existing vacancies are to be filled, and if there is to be an expansion of staffing commensurate with the projected budget increase, State and local agencies would need the equivalent of 2,600 to 2,800 full-time personnel in 1968–69.

At the Federal level, the National Center for Air Pollution Control has about 888 permanent positions budgeted for Fiscal Year 1967 (including positions requested in the pending supplemental appropriations request). The proposed budget for Fiscal 1968 provides for 1,116 permanent positions. The most recent projection of future personnel needs indicated that the National Center's staff would reach 1,900 in Fiscal 1970.

The National Center for Air Pollution Control has steadily increased its expenditures for air pollution training programs. The total for Fiscal 1960 was $250,000. In the current year, grants totalling $3 million have been awarded for graduate training programs at universities, and a total of $685,000 is budgeted for training courses for personnel already in the field of air pollution control. Total enrollment in such courses is expected to reach 1,600.

(*b*) With respect to needs for grants for research, development, and demonstration projects, the following table provides a projection of funds for both direct operations and grants.

[In thousands of dollars]

	1968	1969	1970
1. Research and development on control technology:			
Regular budget projections:			
Direct operations	7,981	9,221	11,121
Grants	4,300	4,600	6,000
Subtotal	12,281	13,821	17,121
Proposed legislation	6,875	20,875	29,500
Total	19,156	34,696	46,621
2. Demonstration of control technology: [1]			
Regular budget projections	3,900	3,900	4,100
Proposed legislation	25,000	49,000	76,000
Total	28,900	52,900	80,100
3. Research on effects of air pollution:			
Regular budget projections:			
Direct operations	5,119	5,429	5,979
Grants	4,300	4,600	6,000
Subtotal	9,419	10,029	11,979
Proposed legislation	125	875	500
Total	9,544	10,904	12,479

[1] Includes pilot plants and other demonstrations.

SENATE COMMITTEE ON PUBLIC WORKS,
Washington, D.C., April 21, 1967.

Dr. JOHN MIDDLETON,
Director, National Center for Air Pollution Control, Department of Health, Education, and Welfare, Washington, D.C.

DEAR DR. MIDDLETON: As I indicated at the end of your testimony, there are several questions on which responses will be most helpful to our consideration of the legislation:

1. Please provide a list of State, local and other agencies receiving Federal grants, the amount and purpose of the grant, and the percentage of total State or local expenditures provided by that grant, and a summary of the grants in terms of amounts authorized, requested and appropriated, the number of grants awarded by State, total and average grant value, and average percentage of total expenditures provided by grants. The above are desired through FY 1966, with estimates for FY 1967 and the subsequent 5 years.

2. What is the estimated annual and cumulative expenditure of the Center on sulfur research directed towards (*a*) health effects and (*b*) emission control methods? What is the projected amount over the next three to five years? Please delineate between inhouse, contracts, grants, and demonstration assistance.

3. Has the Center surveyed or otherwise obtained refined statistics on the availability and costs of low-sulfur coal? I understand that much of this type of coal is owned by the steel industry and is essential for metallurigal use. Is there a breakdown on the reserves and their locations that are available for (*a*) power generation, (*b*) metallurgical, (*c*) industrial, and (*d*) other uses?

4. On page 20 of your prepared statement you indicate that there are certain emissions which may produce injury to human health and damage to property independently of their effects on overall community air quality. Can you provide the Committee with examples of these pollutants and the sources to which they may be attributed?

5. S. 780 provides the Governor with six months, after the effective date of Federal emission standards, to set State standards. Do you believe that this is sufficient time for a State to set standards? How many States now have air pollution control laws so written as to allow this type of activity? Will you provide a list of those States for the record?

6. On page 14 of your remarks you state that emission standards would be based on scientific criteria published pursuant to the provisions of the Clean Air Act. You further state, "In any event, we would publish criteria for a category of pollutants before we would establish emission standards applicable to the sources of those pollutants." If present progress in establishing criteria is any indicator this could mean that emission standards are years away. Is this correct? What criteria are presently being considered? What industries are presently being considered for "national emission standards" based upon the subject criteria? What are the pollutant categories associated with these industries? What are the projected publication times for the above criteria? If authorized by the Congress this year, what are the projected dates for promulgation of emission standards?

7. As relates to acute pollution levels and your organization's surveillance activities, to what extent have you attempted to develop the necessary material to forecast acute exposure levels with sufficient lead time to allow for emergency control before the fact? Has any of the work of the Environmental Science Services Administration proved useful in this endeavor?

I will appreciate your early response to these questions so that the hearing record will be complete.

Sincerely,

EDMUND S. MUSKIE,
U.S. Senator,
Chairman, Subcommittee on Air and Water Pollution.

APRIL 21 LETTER

Question 1. Please provide a list of State, local, and other agencies receiving Federal grants, the amount and purpose of the grant, and the percentage of total State or local expenditures provided by that grant, and a summary of the grants in terms of amounts authorized, requested, and grant value, and average percentage of total expenditures provided by grants. The above are desired through FY 1966, with estimates for FY 1967 and the subsequent five years.

Answer. The attached tables provide the requested information. The tables list grant awards and total program budgets as shown on official award statements. The following comments apply to specific tables:

1966 tables: Awards total more than the amount of appropriations. Additional awards were made possible through the use of unobligated funds in grantees' accounts from prior year's awards. Actual obligations from 1966 appropriation totaled $4,965,632.

1967 tables: It is expected that by June 30, 1967, the entire amount appropriated for fiscal year 1967 will be obligated. Pending applications competing for funds available total more than $2.5 million.

Air pollution control program grants

	Authorized	Requested	Appropratied
Fiscal year—			
1965	(1)	$4,400,000	$4,180,000
1966	(1)	5,000,000	5,000,000
1967	(1)	7,000,000	7,000,000
1968	(1)	[2] 20,259,000	
1969	(1)	[3] 23,500,000	
1970	(1)	[3] 28,000,000	
1971	(1)	[3] 31,000,000	
1972	(1)	[3] 32,000,000	

[1] The Clean Air Act, Public Law 88-206, sec. 104 reads in past as follows; "(a) From the sums appropriated annually for the purposes of this Act but not to exceed 20 per centum of any such appropriation, the Secretary is authorized to make grants to air pollution control agencies. * * *." This restriction to 20 percent of the total appropriation was removed by the 1966 amendments to the act, Public Law 89-675.
[2] From President's budget.
[3] Projected budget requests.

Summary of air pollution control program grants by State

FISCAL YEAR 1965

State	Number of projects	Total grant value	Average grant value	Total program budgets	Percent grant of total
Alabama	4	$162,581	$40,645	$221,632	73.3
Alaska	0				
Arizona	2	132,538	66,269	185,306	71.5
Arkansas	1	38,680	38,680	58,020	66.6
California	3	309,102	103,034	4,792,998	6.4
Colorado	2	124,390	62,195	198,780	62.5
Connecticut	5	111,137	22,227	186,856	59.4
Delaware	0				
District of Columbia	0				
Florida	2	102,813	51,406	156,636	65.6
Georgia	3	76,333	25,444	123,224	61.9
Hawaii	1	23,874	23,874	74,028	32.2
Idaho	0				
Illinois	3	522,500	174,166	1,437,048	36.3
Indiana	4	126,692	31,673	239,352	52.9
Iowa	1	10,400	10,400	15,600	66.6
Kansas	1	24,372	24,372	32,496	75.0
Kentucky	2	57,564	28,782	162,423	35.4
Louisiana	1	33,448	33,448	57,345	58.3
Maine	0				
Maryland	0				
Massachusetts	3	141,034	47,011	251,728	56.0
Michigan	4	166,527	41,831	457,671	36.3
Minnesota	2	80,752	40,376	136,480	59.1
Mississippi	0				
Missouri	1	105,123	105,123	168,614	62.3
Montana	1	10,058	10,058	24,726	40.6
Nebraska	0				
Nevada	1	25,117	25,117	37,243	67.4
New Hampshire	1	12,680	12,680	19,020	66.6
New Jersey	2	258,876	129,438	537,254	48.1
New Mexico	2	20,282	10,141	36,257	55.9
New York	14	514,836	36,774	2,107,117	24.4
North Carolina	6	101,077	16,846	134,771	74.9
North Dakota	1	10,000	10,000	15,000	66.6
Ohio	3	137,958	45,986	223,131	61.8
Oklahoma	3	43,311	14,437	59,082	73.3
Oregon	1	72,598	72,598	117,773	61.6

Summary of air pollution control program grants by State—Continued

FISCAL YEAR 1965—Continued

State	Number of projects	Total grant value	Average grant value	Total program budgets	Percent grant of total
Pennsylvania	4	$341,613	$85,403	$983,570	34.7
Rhode Island	1	7,052	7,052	42,606	16.5
South Carolina	1	10,030	10,030	18,952	52.9
South Dakota	0				
Tennessee	3	45,558	15,186	92,840	49.0
Texas	1	17,974	17,974	43,761	41.0
Utah	0				
Vermont	0				
Virginia	1	1,823	1,823	13,560	13.4
Washington	0				
West Virginia	1	84,914	84,914	150,544	56.4
Wisconsin	0				
Wyoming	0				
Guam	0				
Puerto Rico	1	114,351	114,351	171,529	66.6
Virgin Islands	0				
Total		4,179,968	1,691,764	13,784,973	30.3

FISCAL YEAR 1966

State	Number of projects	Total grant value	Average grant value	Total program budgets	Percent grant of total
Alabama	4	202,071	50,517	284,815	70.9
Alaska	0				
Arizona	2	83,657	41,828	163,925	51.0
Arkansas	1	38,680	38,680	58,020	66.7
California	3	315,203	105,067	5,065,427	6.3
Colorado	3	169,346	56,448	310,449	54.6
Connecticut	6	244,749	40,791	371,204	66.0
Delaware	0				
District of Columbia	1	33,262	33,262	77,847	42.8
Florida	2	93,268	46,634	143,673	64.9
Georgia	4	97,414	24,353	154,703	63.0
Hawaii	1	24,002	24,002	74,220	32.4
Idaho	0				
Illinois	3	522,500	174,166	1,472,678	35.4
Indiana	5	157,348	31,469	325,208	48.4
Iowa	1	10,400	10,400	15,600	66.7
Kansas	1	74,291	74,291	99,054	75.0
Kentucky	2	239,676	119,838	380,938	63.0
Louisiana	1	58,055	58,055	93,937	61.8
Maine	0				
Maryland	0				
Massachusetts	3	175,000	58,333	296,294	59.0
Michigan	5	269,398	53,879	687,727	39.2
Minnesota	3	103,678	34,559	170,870	60.7
Mississippi	0				M
Missouri	4	239,848	59,962	483,155	49.6
Montana	1	10,058	10,058	32,156	31.2
Nebraska	0				M
Nevada	1	27,615	27,615	40,575	68.1
New Hampshire	0				
New Jersey	1	250,000	250,000	659,037	37.9
New Mexico	2	23,645	11,822	41,590	56.9
New York	15	579,704	38,646	2,394,500	24.3
North Carolina	7	128,655	18,379	174,163	73.9
North Dakota	1	10,000	10,000	15,000	66.6
Ohio	5	208,238	41,647	552,823	37.7
Oklahoma	3	49,945	16,648	68,593	72.8
Oregon	2	126,155	63,077	297,631	42.4
Pennsylvania	4	416,962	104,240	1,143,146	36.5
Rhode Island	1	7,052	7,052	42,606	16.6
South Carolina	2	54,634	27,317	86,032	63.5
South Dakota	0				
Tennessee	3	54,033	18,011	105,755	51.0
Texas	2	106,304	53,152	173,081	61.4
Utah	0				
Vermont	0				
Virginia	0				
Washington	1	71,976	71,976	138,115	52.2
West Virginia	1	147,640	147,640	253,990	58.1
Wisconsin	1	12,978	12,978	200,257	6.5
Wyoming	0				
Guam	0				
Puerto Rico	1	117,156	117,156	175,736	66.7
Virgin Islands	0				
Total		5,554,596	2,183,948	17,302,652	32.2

Summary of air pollution control program grants by State—Continued

FISCAL YEAR 1967

State	Number of projects	Total grant value	Average grant value	Total program budgets	Percent grant of total
Alabama	4	$121,642	$30,410	$195,991	62.0
Alaska	0				
Arizona	2	85,000	42,500	169,211	50.2
Arkansas	1	38,680	38,680	58,020	66.7
California	4	391,483	97,870	5,317,141	7.3
Colorado	5	342,613	68,522	647,700	52.9
Connecticut	10	295,461	29,546	445,640	66.4
Delaware	0				
District of Columbia	1	36,700	36,700	77,708	47.3
Florida	4	188,457	47,114	296,185	63.7
Georgia	4	73,777	18,444	125,168	59.0
Hawaii	1	25,166	25,166	75,966	33.2
Idaho	1	17,982	17,982	26,982	66.7
Illinois	3	522,500	174,166	1,475,876	35.5
Indiana	7	204,800	29,257	408,175	50.2
Iowa	1	10,400	10,400	26,767	38.8
Kansas	1	74,214	74,214	98,952	75.0
Kentucky	1	196,828	196,828	316,666	62.1
Louisiana	1	63,448	63,448	103,213	61.5
Maine	0				
Maryland	0				
Massachusetts	4	105,020	26,255	228,574	46.0
Michigan	4	370,918	92,729	796,370	46.5
Minnesota	2	93,678	46,829	155,870	60.2
Mississippi	0				
Missouri	5	382,000	76,400	709,147	53.9
Montana	2	36,900	18,450	70,811	52.2
Nebraska	0				
Nevada	1	32,424	32,424	46,986	69.0
New Hampshire	1	18,680	18,680	31,160	60.0
New Jersey	2	260,960	130,480	827,021	31.6
New Mexico	2	62,526	31,263	97,799	68.2
New York	15	608,714	40,580	5,466,768	11.2
North Carolina	9	163,448	18,160	221,945	73.7
North Dakota	1	10,000	10,000	15,000	66.7
Ohio	7	244,338	34,705	611,506	40.0
Oklahoma	3	42,305	14,101	61,364	69.0
Oregon	3	104,645	34,881	279,495	37.5
Pennsylvania	6	453,086	75,514	1,279,334	35.5
Rhode Island	0				
South Carolina	3	80,101	26,700	122,641	65.4
South Dakota	0				
Tennessee	3	41,748	13,916	87,830	47.6
Texas	3	108,892	36,297	127,763	85.3
Utah	1	20,726	20,726	39,268	52.8
Vermont	0				
Virginia	3	31,936	10,645	72,061	44.4
Washington	2	126,690	63,345	211,067	60.0
West Virginia	2	159,159	79,579	273,894	58.1
Wisconsin	1	12,978	12,978	226,651	57.0
Wyoming	0				
Guam	0				
Puerto Rico	1	117,156	117,156	201,678	58.0
Virgin Islands	0				
Total		6,378,179	2,084,040	22,121,364	28.9

Summary of air pollution control program grants

FISCAL YEAR 1965

Grantee	Purpose	Grant award	Total program budget	Federal percent of total
Alabama State	Develop	$10,000	$15,000	66.6
Jefferson County	do	120,510	162,204	74.4
Huntsville	Establish	10,000	15,000	66.6
Mobile County	Develop	22,071	29,428	75.0
Maricopa County, Ariz	Establish	107,551	151,984	70.7
Pima County	Develop	24,987	33,322	74.9
Arkansas State	Establish	38,680	58,020	66.6
Los Angeles County, Calif	Improve	174,425	3,461,636	5.0
San Bernardino County	do	76,570	283,255	27.0
Bay Area APCD, San Francisco	do	58,107	1,048,107	5.5
City and county of Denver, Colo	do	88,476	150,894	58.6
Tri-County, Aurora	Establish	35,914	47,886	75.0
Connecticut State	Develop	47,180	89,263	52.8
Bridgeport	Establish	22,208	34,063	65.1
Middletown	Develop	12,449	19,020	65.4
Fairfield	do	15,100	22,978	65.7
Stratford	do	14,200	21,532	65.9
Dade County, Fla	Improve	63,720	104,190	61.1
Palm Beach County	Establish	39,093	52,446	74.5
Georgia State	Develop	42,488	78,097	54.5
Fulton County	do	18,000	24,000	75.0
Macon-Bibb County	do	15,845	21,127	75.0
Hawaii State	Improve	23,874	74,028	32.2
Illinois State	do	79,416	124,270	63.9
Chicago	do	393,000	1,162,694	33.8
Cook County	do	50,084	150,084	33.3
Indiana State	do	38,100	74,590	51.0
East Chicago	do	14,680	33,345	44.0
Gary	do	62,765	106,185	59.1
Evansville	do	11,147	25,232	44.1
Cedar Rapids, Iowa	Develop	10,400	15,600	66.6
Kansas City-Wyandotte County, Kans	do	24,372	32,496	75.0
Kentucky State	do	36,564	54,846	66.6
Jefferson County	Improve	21,000	107,577	19.5
Louisiana State	Establish	33,448	57,345	58.3
Worcester, Mass	do	23,214	34,833	66.6
Boston, metropolitan area	Improve	84,820	172,895	49.0
Springfield metropolitan area	Develop	33,000	44,000	75.0
Muskegon County, Mich	do	15,885	21,180	75.0
Wayne County	Improve	89,964	133,421	67.4
Wyandotte	do	17,893	27,090	66.0
Detroit	do	42,785	275,890	15.5
St. Paul, Minn	do	42,857	69,393	61.7
Minneapolis	do	37,895	67,087	56.4
St. Louis County, Mo	Establish	105,123	168,614	62.3
Montana State	Develop	10,058	24,726	40.6
Reno-Sparks-Washoe County, Nev	do	25,117	37,243	67.4
New Hampshire State	Develop	12,680	19,020	66.6
New Jersey State	Improve	250,876	522,754	47.9
East Orange	Develop	8,000	14,500	55.1
New Mexico	do	14,022	21,036	66.6
Albuquerque	Improve	6,260	15,221	41.1
New York State	do	112,391	502,539	22.3
New Rochelle	Develop	6,389	11,976	53.3
Erie County	do	75,720	113,580	66.6
Broome County	do	7,894	11,841	66.6
Dutchess County	Establish	3,200	4,830	66.6
Chemung County	Develop	6,169	8,226	74.9
Nassau County	do	54,150	149,919	36.1
Schenectady	do	2,917	4,376	66.6
Albany County	do	2,940	4,410	66.6
Mount Vernon	do	5,502	8,254	66.6
Yonkers	do	8,312	12,468	66.6
Columbia County	do	3,836	5,754	66.6
Niagara County	do	35,244	46,992	75.0
New York City	Improve	190,172	1,221,952	15.5
Guilford County, N.C	Develop	18,292	24,300	74.9
Durham County	do	13,379	17,839	74.9
Buncombe County	do	24,949	33,265	75.0
Rowan County	do	12,651	16,868	75.0
New Hanover County	do	12,524	16,699	74.9
Gaston County	do	19,282	25,710	74.9
North Dakota State	do	10,000	15,000	66.6
Lorain, Ohio	Establish	19,386	29,079	66.6
Akron	Develop	94,155	130,540	72.1
Toledo	Improve	24,417	63,512	38.4
Oklahoma State	Develop	8,000	12,000	66.6

See footnotes at end of table, p. 2354.

Summary of air pollution control program grants—Continued

FISCAL YEAR 1965—Continued

Grantee	Purpose	Grant award	Total program budget	Federal percent of total
Oklahoma City-County	Develop	$10,177	$13,570	74.9
Tulsa City-County	do	25,134	33,512	75.0
Portland, Oreg	Improve	72,598	117,773	61.6
Pennsylvania State	do	56,800	247,390	22.9
Macungie	Establish	520	780	66.6
Philadelphia	Improve	124,662	365,295	34.1
Allegheny County	do	159,631	370,105	43.1
Puerto Rico	Develop	114,351	171,529	66.6
Providence, R.I	Improve	7,052	42,606	16.5
Spartanburg, S.C	do	10,030	18,952	52.9
Tennessee State	Develop	16,914	25,391	66.6
Chattanooga	Improve	13,521	36,785	36.7
Nashville and Davidson County	Develop	15,123	30,664	49.3
Texas State	do	17,974	43,761	41.0
Roanoke, Va	Improve	1,823	13,560	13.4
West Virginia	do	84,914	150,544	56.4
Total		4,179,968	13,784,973	30.3

FISCAL YEAR 1966

Alabama State	Develop	$50,000	$75,000	66.7
Jefferson County	do	120,000	165,387	72.5
Huntsville	Establish	10,000	15,000	66.6
Mobile County	do	22,071	29,428	75.0
Maricopa County, Ariz	Establish	58,657	130,425	45.0
Pima County	Develop	25,000	33,500	74.6
Arkansas State	Establish	38,680	58,020	66.7
Los Angeles County, Calif	Improve	179,591	3,670,532	4.9
San Bernardino County	do	43,800	268,304	16.4
Bay Area, APCD, San Francisco	do	91,812	1,126,591	8.2
Colorado State	Establish	20,060	75,840	26.5
City and county of Denver	Improve	104,286	174,609	59.8
Tri-County, Aurora	Establish	45,000	60,000	75.0
Connecticut State	Develop	[1] 128,068	190,618	67.1
Bridgeport	Establish	22,208	34,063	65.2
Middletown	Develop	14,356	21,655	66.3
Fairfield	do	21,600	32,840	65.8
Stratford	do	20,624	31,376	65.7
New Haven	do	37,893	60,652	62.5
District of Columbia	Improve	33,262	77,847	42.8
Dade County, Fla	do	52,220	88,857	58.7
Palm Beach County	Establish	41,048	54,816	74.8
Georgia State	Develop	46,452	84,967	54.7
Fulton County	do	22,500	30,000	75.0
Macon-Bibb County	do	15,479	20,639	75.0
Chatham County	do	12,983	19,097	68.0
Hawaii State	Improve	24,002	74,220	32.4
Illinois State	do	79,416	156,466	50.8
Chicago	do	393,000	1,162,694	33.8
Cook County	do	50,084	153,518	32.6
Indiana State	do	41,580	79,810	52.0
East Chicago	do	19,340	40,335	47.9
Gary	do	62,765	106,185	59.1
Evansville	do	11,147	25,232	44.2
Indianapolis	do	22,516	73,646	30.6
Cedar Rapids, Iowa	Develop	10,400	15,600	66.7
Kansas City-Wyandotte County, Kans	do	74,291	99,054	75.0
Kentucky State	do	42,848	64,272	66.7
Do	Establish	196,828	316,666	62.2
Louisiana State	do	58,055	93,937	61.8
Worcester, Mass	do	22,000	33,619	65.5
Boston metropolitan area	Improve	120,000	218,675	54.8
Springfield	Develop	33,000	44,000	75.0
Michigan State	Establish	54,648	116,972	46.7
Muskegon County	Develop	15,885	21,180	75.0
Wayne County	Improve	133,500	191,469	69.8
Wyandotte	do	13,632	20,698	65.9
Detroit	do	51,733	336,953	15.4
Minnesota State	Develop	10,000	15,000	66.6
St. Paul	Improve	55,783	88,783	62.8
Minneapolis	do	37,895	67,087	56.5
Missouri State	Establish	45,865	68,800	66.7
St. Louis County	do	120,000	190,852	62.8
St. Louis	Improve	42,768	176,553	24.2

See footnotes at end of table, p. 2354.

Summary of air pollution control program grants—Continued

FISCAL YEAR 1966—Continued

Grantee	Purpose	Grant award	Total program budget	Federal percent of total
Greene County—Springfield	Develop	$31,215	$46,951	66.4
Montana State	do	10,058	32,156	31.2
Reno-Sparks-Washoe, Nev	Establish	27,615	40,575	68.1
New Jersey State	Improve	250,000	659,037	37.9
New Mexico	Develop	17,357	26,036	66.7
Alburquerque	Improve	6,288	15,554	40.4
New York State	Improve	120,000	513,953	23.4
New Rochelle	Establish	6,400	11,990	53.4
Erie County	Develop	72,193	108,291	66.7
Broome County	do	10,233	15,349	66.7
Dutchess County	do	5,343	8,015	66.7
Chemung County	do	6,206	8,275	75.0
Nassau County	do	101,850	237,496	43.0
Schenectady	do	4,133	6,200	66.7
Albany County	do	3,350	5,025	66.7
Mount Vernon	do	5,502	8,254	66.7
Yonkers	do	9,000	13,675	65.8
Columbia County	do	4,066	6,100	66.7
Niagara County	do	37,500	50,000	75.0
New York City	Improve	188,000	1,389,913	13.6
Westchester County	Develop	5,928	11,964	49.6
Guilford County, N.C	Develop	19,202	25,605	75.0
Durham County	do	13,379	18,503	72.3
Buncombe County	do	23,945	31,927	75.0
Rowan County	do	12,634	16,851	75.0
New Hanover County	do	12,524	16,725	75.0
Gaston County	do	14,270	20,950	68.1
Mecklenburg County	do	32,701	43,602	75.0
North Dakota	do	10,000	15,000	66.6
Lorain, Ohio	Establish	19,386	29,079	66.7
Akron	Develop	94,155	130,540	72.2
Toledo	Improve	24,417	63,512	38.4
Cleveland	do	34,922	276,652	12.6
Canton	Develop	35,358	53,040	66.7
Oklahoma State	do	12,000	18,000	66.6
Oklahoma City	do	10,177	13,569	75.0
Tulsa City-County	do	27,768	37,024	75.0
Oregon State	Improve	53,557	179,858	29.8
Portland	do	72,598	117,773	61.7
Pennsylvania State	do	84,475	335,455	25.2
Macungie	Establish	520	780	66.7
Philadelphia	Improve	172,336	436,806	39.5
Allegheny County	do	159,631	370,105	43.2
Puerto Rico	Develop	117,156	175,736	66.7
Providence, R.I	Improve	7,052	42,636	16.6
South Carolina	Establish	45,421	68,131	66.7
Spartanburg	Improve	9,213	17,901	51.4
Tennessee State	Develop	21,523	32,285	66.7
Chattanooga	Improve	15,740	40,610	38.7
Nashville and Davidson County	Develop	16,770	32,860	51.0
Texas State	do	57,549	105,366	54.6
Dallas	do	48,755	67,715	72.1
Seattle-King County, Wash	do	71,976	138,115	52.2
West Virginia	Improve	147,640	253,990	58.1
Milwaukee County, Wis	do	12,978	200,257	06.5
Total		5,554,596	17,302,652	32.2

FISCAL YEAR 1967

Alabama State	Develop	$25,000	$50,000	50.0
Jefferson County	do	75,000	115,497	64.9
Huntsville	Establish	9,822	14,733	66.7
Mobile County	Develop	[2] 11,820	15,761	75.0
Maricopa County, Ariz	Establish	60,000	135,615	44.3
Pima County	do	25,000	33,596	74.4
Arkansas State	do	[2] 38,680	58,020	66.7
Los Angeles County, Calif	Improve	198,607	3,758,227	05.2
San Bernardino County	do	43,800	295,867	14.8
Bay Area APCD, San Francisco	do	[2] 104,031	1,195,479	8.7
Monterey County	Establish	45,045	67,568	66.7
Colorado State	do	123,060	316,508	38.9
Denver-City-County	Improve	121,644	200,646	60.7
Tri-County Health District	do	56,250	75,000	75.0
Jefferson County	Establish	15,000	20,000	75.0
Pueblo County	do	26,659	35,546	75.0

See footnotes at end of table, p. 2354.

Summary of air pollution control program grants—Continued

FISCAL YEAR 1967—Continued

Grantee	Purpose	Grant award	Total program budget	Federal percent of total
Connecticut State	Establish	[2] $89,066	$151,601	58.8
Bridgeport	do	22,208	34,062	65.2
Middletown		[3] 14,356		
Fairfield	do	[2] 21,600	32,400	66.7
Stratford	do	[2] 20,624	30,937	66.7
New Haven	Develop	[2] 36,039	61,905	58.2
Stamford	do	27,650	41,565	66.6
Greenwich	do	16,108	25,301	63.6
Norwalk	do	24,310	36,535	66.6
Milford	do	23,500	31,334	75.0
District of Columbia	Improve	36,700	77,708	47.3
Dade County, Fla	Improve	84,225	131,530	64.0
Palm Beach County	Establish	[2] 43,066	57,431	75.0
Manatee County	do	22,926	55,168	41.6
Hillsborough County	do	38,240	52,056	73.4
Georgia State	Develop	27,500	48,735	56.5
Fulton County	Establish	[2] 22,500	37,500	60.0
Macon-Bibb County	do	[2] 11,432	20,324	56.3
Chatham County	Develop	12,345	18,609	66.4
Hawaii State	Improve	25,166	75,966	33.2
Idaho State	Develop	17,982	26,982	66.7
Illinois State	Improve	79,416	156,466	50.7
Chicago	do	393,000	1,162,694	33.8
Cook County	do	50,084	156,716	32.0
Indiana State	do	42,900	81,790	52.5
East Chicago	do	19,340	40,335	48.0
Gary	do	62,765	106,185	59.2
Evansville		[2] 11,147	31,721	35.1
Indianapolis	do	[2] 28,248	84,744	33.4
Michigan City	Develop	4,400	7,400	59.4
Hammond	do	36,000	56,000	64.3
Cedar Rapids, Iowa	Establish	10,400	26,767	38.8
Kansas City-Wyandotte County, Kans	do	74,214	98,952	75.0
Kentucky State	do	[2] 196,828	316,666	62.1
Louisiana State	do	63,448	103,213	61.5
Worcester, Mass	Establish	22,000	35,063	62.7
Boston metropolitan area	Improve	40,050	134,350	29.9
Springfield metropolitan area	Establish	33,000	44,000	75.0
Fitchburg	do	9,970	15,161	65.8
Michigan State	do	74,800	147,200	50.8
Muskegon	do	15,885	21,180	75.0
Wayne County	Improve	133,500	193,400	69.0
Detroit	do	146,733	434,590	33.8
St. Paul, Minn	do	55,783	88,783	62.8
Minneapolis	do	[2] 37,895	67,087	56.5
Missouri State	Establish	54,000	81,000	66.7
Greene County-Springfield	Develop	[2] 30,732	47,840	64.2
St. Louis County	Establish	129,000	209,884	61.5
St. Louis City	Improve	89,568	252,373	35.5
Kansas City	Develop	78,700	118,050	66.7
Montana State	do	24,918	47,016	53.0
Missoula	do	11,982	23,795	50.4
Reno-Sparks-Washoe County, Nev	Establish	32,424	46,986	69.0
New Hampshire State	Improve	18,680	31,160	60.0
New Jersey State	do	250,000	808,081	30.9
East Orange	Develop	10,960	18,940	58.0
New Mexico State	do	8,678	13,162	66.0
Albuquerque	Improve	53,848	78,637	68.4
New York State	Improve	[2] 140,000	2,445,280	05.7
New Rochelle	Establish	10,300	17,840	57.8
Erie County	do	72,193	108,290	66.7
Broome County	do	10,233	15,416	66.3
Dutchess County	do	5,343	8,134	65.7
Nassau County		101,850	237,496	42.8
Schenectady	do	4,133	6,370	64.9
Albany County	do	3,350	5,025	66.7
Mount Vernon	do	5,502	8,253	66.7
Yonkers	do	9,000	13,500	66.7
Columbia County	do	4,066	6,099	66.7
Niagara County	do	37,500	50,000	75.0
New York City	Improve	[2] 188,000	2,516,964	07.5
Westchester County	Develop	[2] 11,619	20,601	56.4
Rensselaer County	do	5,625	7,500	75.0
Guilford County, N.C	Establish	19,202	25,605	75.0
Durham County	do	13,379	17,866	74.9
Buncombe County	do	13,246	17,661	75.0
Rowan County	do	12,651	16,868	75.0

See footnotes at end of table, p. 2354.

Summary of air pollution control program grants—Continued

FISCAL YEAR 1965—Continued

Grantee	Purpose	Grant award	Total program budget	Federal percent of total
New Hanover County	Establish	$12,524	$16,725	74.9
Gaston County	do	14,270	20,970	68.0
Mecklenburg County	Develop	32,701	45,618	71.7
Beaufort County	do	28,052	37,402	75.0
Cleveland County	do	17,423	23,230	75.0
North Dakota State	Establish	[2] 10,000	15,000	66.7
Lorain, Ohio	do	19,386	29,079	66.7
Akron	do	94,155	130,540	72.1
Toledo	Improve	24,417	67,455	36.2
Cleveland	do	34,922	276,652	12.6
Canton	Develop	35,358	53,040	66.7
Steubenville	do	19,000	29,000	65.5
Portsmouth	Establish	17,100	25,740	66.5
Oklahoma State	Develop	4,000	10,290	38.8
Oklahoma City-County	Establish	[2] 10,177	13,570	75.0
Tulsa City-County	do	[2] 28,128	37,504	75.0
Oregon State	Improve	54,399	187,393	29.1
Portland	do	31,022	49,492	62.7
Lane County	do	19,224	42,610	45.1
Pennsylvania State	Improve	84,475	369,475	22.9
Macungie	Establish	520	780	66.7
Philadelphia	Improve	178,460	445,992	40.0
Allegheny County	do	159,631	423,087	37.7
York	Establish	15,000	20,000	75.0
Lehigh Valley	Develop	15,000	20,000	75.0
Puerto Rico	Establish	[2] 117,156	201,678	58.0
South Carolina State	do	45,421	70,606	64.3
Spartanburg	Improve	9,213	18,079	50.9
Charleston County	Develop	25,467	33,956	75.0
Tennessee State	do	8,440	12,660	66.7
Chattanooga	Improve	16,538	42,310	39.1
Nashville-Davidson County	Establish	16,770	32,860	51.0
Texas State	do	57,549	107,610	53.5
Dallas		[3] 36,235		
Lubbock City-County	Develop	15,108	20,153	75.0
Utah State	do	20,726	39,268	52.7
Roanoke County, Va.	do	12,096	16,128	75.0
Hopewell	do	8,300	12,450	66.7
Richmond	Establish	11,040	43,483	26.6
Seattle-King County, Wash.	Develop	110,040	188,867	58.2
Clark County	do	16,650	22,200	75.0
West Virginia State	Improve	147,640	253,990	58.2
Wheeling	Develop	11,519	19,904	57.8
Milwaukee, Wis.	Improve	12,978	226,651	57.0
Total		6,378,179	22,121,364	28.9

[1] Includes supplement to 1965 grant.
[2] Based on pending application.
[3] No application received, funds committed or reserved.

Question 2. What is the estimated annual and cumulative expenditure of the Center on sulfur research directed towards (*a*) health effects and (*b*) emission control methods? What is the projected amount over the next three to five years? Please delineate between in-house, contracts, grants, and demonstration assistance.

Answer. The attached table provides the requested information for Fiscal Years 1967 through 1970.

Sulfur research

[In thousands of dollars]

	1967	1968	1969	1970	Total
Emission control, total	[1] $6,100	[2] $30,000	[2] $40,000	[2] $40,000	$116,100
In-house	462	900	1,000	1,000	3,362
Contracts	5,638	29,100	39,000	39,000	112,738
(Demonstrations)		(2,500)	(7,000)	(10,000)	(19,500)
Health effects, total	1,226	1,334	1,751	1,697	6,008
In-house	646	700	750	750	2,846
Contracts	434	490	740	740	2,404
Research grants	146	144	261	207	758
Related studies, total [3]	1,568	1,919	2,967	3,275	9,729
In-house	1,134	1,211	1,400	1,400	5,145
Contracts		283	600	600	1,483
Research grants	434	425	967	1,275	3,101
Total sulfur research	8,894	33,253	44,718	44,972	131,837

[1] Includes proposed supplemental.
[2] Estimates under the proposed Air Quality Act of 1967.
[3] These include sulfur-related studies concerned with chemical analyses, measurement, meteorological, and agricultural aspects, etc.

Question 3. Has the Center surveyed or otherwise obtained refined statistics on the availability and costs of low-sulfur coal? I understand that much of this type of coal is owned by the steel industry and is essential for metallurgical use. Is there a breakdown on reserves and their locations that are available for (*a*) power generation, (*b*) metallurgical, (*c*) industrial, and (*d*) other uses?

Answer. The availability of low sulfur coal for all customers must be associated with costs for such coals. In general, low sulfur coals are more costly than high sulfur coals; this is because of the greater demand by customers such as the steel and metallurgical industries, here and abroad, and the greater difficulty in mining, e.g., deep mines, thinner seams, and its occurrence in pockets. Large tonnages of low sulfur bituminous coals are available from southern West Virginia, Virginia, Eastern Kentucky, Alabama and the Mountain States. While the production of much of this low sulfur coal is for steel and metallurgical purposes, considerable tonnages are used for the generation of electric power in the Carolinas and Virginia. A breakdown on production and specific tonnages for power production was as follows in 1965:

[In thousands of tons]

	Production of bituminous coal under 1 percent sulfur	Use of such coal for power plants
West Virginia	85,000	5,000
Virginia	27,000	8,500
Eastern Kentucky	35,000	1,000
Mountain States	16,000	7,500
Alabama	6,000	2,000
Total	169,000	24,000

Some 15,000,000 tons of anthracite coal, lower than 1% in sulfur, was mined in Pennsylvania in 1965, and over 1,000,000 tons of this anthracite was used for power generation in Pennsylvania.

About 3,000,000 tons of low sulfur lignite (0.7%) was produced in the Dakotas and Montana, 2,000,000 tons of which was consumed by power plants in those states and in Minnesota and Montana.

The cost of low sulfur bituminous coal will depend upon the BTU value, ash content, sulfur content, and shipping charges. Adjustments to lower such costs can be expected when large tonnages and long-term contracts are negotiated and when unit train rail rates are in effect. A high BTU (13,500), low ash (4%), and low sulfur (0.7%) coal may have an FOB cost of around $7.00 per ton, while lower BTU (12,000), higher ash (14%), and higher sulfur (1.0%) coal may be obtained for around $5.00 per ton. The freight rate on coal from these areas is around one cent per ton mile.

As for the reserves of low sulfur coal, these appear adequate for many years. According to the Bureau of Mines Information Circular 8312 of 1966, some one trillion tons of low sulfur coals are in reserve in this country. It is difficult to precisely allocate these reserves to metallurgical, power plant, and other uses. The foreign demands, as well as domestic needs, could vary considerably because of national and international economics, the state of metallurgical and power plant technologies, and the emergence of nuclear power. It seems reasonable that the supplies of low sulfur coals will be adequate for an expanding economy for many years, if price can be ignored. These reserves may be stated to be as follows for the States having the most reserves.

[In billions of tons]

Bituminous:	
Alabama	2
Alaska	21
Colorado	62
East Kentucky	22
New Mexico	11
Oklahoma	1
Pennsylvania	1
Utah	22
Virginia	8
Washington	2
West Virginia	47
Wyoming	13
Total	212
Subbituminous and lignite:	
Alaska	71
Colorado	18
Montana	215
New Mexico	51
North Dakota	319
South Dakota	2
Washington	4
Wyoming	108
Total	788
Anthracite:	
Alaska	2
Pennsylvania	12
Total	14
Grand total	1,014

In the past, approximately 80 percent of the total of the low sulfur coal production has been used for domestic and foreign metallurgical purposes. Should this same percentage be used in the future at the same rate of consumption, and considering only the bituminous and anthracite reserves, there would be suffi-

cient reserves of these coals to last over 1,000 years. The sub-bituminous and lignite coals would probably not be used for metallurgical purposes; consequently, these sources could be used for other combustion, and—combined with the low sulfur bituminous coals not used for metallurgical purposes—would suffice for hundreds of years of expanded consumption.

As to the ready mineability of these reserve coals, no assessment has been made. Also, information on the ownership of these coals, particularly the captive reserves of the metallurgical industry and those under government domain, is not available.

Along with coal, one should consider the availability of low sulfur oils for power and heating. At present, most of these fuels in the form of residual, #6, or Bunker C, are high in sulfur. Small quantities of the domestic residual oils are used for metallurgical purposes and power, but the production of these oils is being phased out in favor of more profitable products. This then leaves the imported oils as the only large sources of such fuels.

Unfortunately the foreign residual oils, which are largely of Venezuelan sources, are very high in sulfur. A few world sources offer low sulfur residual oil and these are: North Africa, Nigeria, Indonesia and Sumatra, Argentina and Romania. It is of interest to note that larger and larger volumes of crude from North Africa, Nigeria and Indonesia are being imported under license. The amounts of low sulfur residual oil being imported are insignificant. Again, the present refining techniques appeal to convert nearly all of the low sulfur crudes into more valuable products than residual oil.

Question 4. On page 20 of your prepared statement you indicate that there are certain emissions which may produce injury to human health and damage to property independently of their effects on overall community air quality. Can you provide the Committee with examples of these pollutants and sources to which they may be attributed?

Answer. All air pollutant sources are of interest from two points of view: 1. Their importance in increasing the amount of pollutants in the total air envelope over an area, along with pollutants emitted from other sources, if any; and 2. Their importance in causing or contributing to concentrations of pollutants in a more limited area in the vicinity of the source.

Pollutants of greatest concern with regard to the total air envelope (Item No. 1) are those that arise from a multitude of sources. Examples are sulfur oxides, nitrogen oxides, hydrocarbons, and particulate matter, all of which are emitted by a great number of sources of several types. Total air envelope pollution is generally of more concern in larger cities, and in both larger and smaller cities in which atmospheric ventilation is poor, such as in a valley or topographic basin.

In addition to concern because of increasing pollutant levels in the total air envelope, pollutants may cause problems because of high concentrations in a more limited area in the vicinity of individual sources. Concern about pollution levels in the vicinity of individual sources may arise in connection with the same pollutants that are of concern in regard to the total air envelope, as well as for all other pollutants emitted by only one or a very few sources. This more limited kind of problem is of concern in all areas and for all pollutants. Three typical examples of such problems follow.

1. In a large city where coal and residual oil are used as fuel, there are many sources of sulfur dioxide. Concentrations of this pollutant are of concern throughout the community, because the total air envelope is contaminated due to the combined effect of emissions from thousands of sources. A generalized mission reduction program is needed to reduce the concentration of sulfur dioxide throughout the area. Also in the community is a sulfuric acid plant which emits sulfur dioxide in large amounts from a relatively short stack. In the immediate area surrounding this plant, sulfur dioxide concentrations are higher than at any other location. This one plant, by itself, is responsible for concentrations of sulfur dioxide in excess of those specified in air quality standards. Therefore, emissions from this plant must be reduced, or a higher stack must be provided, or both, so that the total concentration of sulfur dioxide near the plant meets the air quality standards, considering the combined contributions of the sulfuric acid plant itself and all other sources, after emission reduction has been put into effect. Emissions from the acid plant must also be minimized as a part of the generalized community-wide emission reduction program.

2. A sulfuric acid plant is located in a community in which natural gas is the only fuel commonly used in a stationary sources. In general, sulfur dioxide

concentrations in the community are lower than prescribed by the air quality standards. However, in a limited area near the surfuric acid plant, sulfur dioxide concentrations are higher than prescribed in the air quality standards. Therefore, emissions from the plant must be reduced or a higher stack must be provided, or both, so that the concentrations of sulfur dioxide at locations surrounding the plant do not exceed the air quality standards. Contributions to air concentrations near the plant due to other sources are very low and have only a minor influence on emission control needs at the acid plant.

3. In a large city, concentrations of hydrogen sulfide are nearly zero and of no concern, except that in one neighborhood, the odor of hydrogen sulfide is causing problems. The odors come from a coke plant and affect an area lying within one-half mile of the source. The only control of hydrogen sulfide needed in this community is related to the coke plant. Emissions from this plant must be reduced, or a higher stack must be provided, or both, to ensure that concentration of hydrogen sulfide in the air in the area surrounding the plant do not exceed that specified in the air quality standard. No other control action is needed.

Question 5. S. 780 provides the Governor with six months, after the effective date of Federal emission standards, to set State standards. Do you believe that this is sufficient time for a State to set standards? How many States now have air pollution control laws so written as to allow this type of activity? Will you provide a list of those States for the record?

Answer. The Federal emission standards would be intended to insure that emissions from industrial sources of air pollution do not, in themselves, produce adverse effects on public health and welfare. In nearly all instances, achieving the degree of control needed to prevent such direct effects from occurring will necessitate the full use of available control technology. As a practical matter, then, States would be taking appropriate action by adopting and enforcing the standards published by the Secretary of Health, Education, and Welfare. Six months would certainly be an adequate period for such action, even where State laws require the holding of hearings before adoption of standards.

A total of 37 States now have laws which permit adoption of emission standards for the control of air pollution. Of these, Colorado is the only one in which the adoption of standards requires action by the State legislature; in the others, standards can be promulgated through administrative action by the State agency responsible for control of air pollution. The 37 States are Alaska, Arizona, Arkansas, Colorado, Delaware, Florida, Georgia, Hawaii, Idaho, Illinois, Indiana, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Mississippi, Missouri, Montana, Nevada, New Jersey, New Mexico, New York, North Dakota, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Utah, Virginia, Washington, West Virginia, and Wyoming.

Question 6. On page 14 of your remarks, you state that emission standards would be based on significant criteria published pursuant to the provisions of the Clean Air Act. You further state "in any event we would publish criteria for a category of pollutants before we would establish emission standards applicable to the sources of those pollutants." If present progress in establishing criteria is any indicator this could be that the emission standards are years away. Is this correct? What criteria are presently being considered? What industries are presently being considered for "National Emission Standards" based upon the subject criteria? What are the pollutant categories associated with these industries? What are the projected publication times for the above criteria? If authorized by the Congress this year, what are the projected dates for promulgation of emission standards?

Answer. Preparation of air quality criteria is being accelerated. This subject is discussed in detail in the response to Question 1 of the March 31 letter to Dr. Middleton.

Table A lists the industries and pollutant categories which we expect to consider first in connection with the development of national emission standards. Table B lists those which are most likely to be considered after those included in the first list.

Table A

1. Integrated steel mills: Particulate matter, smoke, carbon monoxide, and fluorides.

Table A—Continued

2. Large steam-electric generating stations: Particulate matter and smoke.
3. Non-ferrous smelters: Sulfur oxides, particulate matter, and various metals.
4. Petroleum refineries: Sulfur compounds, hydrocarbons, smoke, particulate matter and odorous matter.
5. Portland cement plants: Particulate matter and sulfur compounds.
6. Sulfuric acid plants: Sulfur dioxide, sulfuric acid mist, and sulfur trioxide.
7. Grey iron and steel foundries: Particulate matter, smoke, and odorous matter.
8. Ferro-alloy plants: Particulate matter.
9. Kraft pulp mills: Sulfur compounds, particulate matter, odorous matter, and possibly chlorine.
10. Hydrochloric acid plants: Hydrochloric acid mist and gas, possibly chlorinated hydrocarbons, and sulfuric acid.

Table B

1. Nitric acid plants: Nitrogen oxides.
2. Bulk storage of gasoline: Hydrocarbons.
3. Soap and detergent plants: Particulate matter and odorous matter.
4. Caustic and chlorine plants: Chlorine, possibly carbon monoxide and particulate matter.
5. Calcium carbide manufacturing: Particulate matter and possibly acetylene.
6. Phosphate fertilizer plants: Fluorides, particulate matter, and ammonia.
7. Lime plants: Particulate matter.
8. Aluminum ore reduction plants: Fluoride and particulate matter.
9. Phosphoric acid plants: Acid mist and fluorides.
10. Coal cleaning plants: Particulate matter.

Progress in the development and publication of national emission standards for major industrial sources of air pollution would depend on such factors as the availability of funds and personnel, completion of air quality criteria pertaining to pollutants for which emission standards would be established, and the time required to conduct any technical investigations which may be necessary and to undertake appropriate consultation with the affected industries and with State and local air pollution control officials. Assuming that development of such standards is authorized by the Congress before the end of calendar 1967, and assuming that none of the factors cited above results in unusual delay, it is anticipated that emission standards for as many as 10 industry-pollutant combinations could be prepared by the end of calendar 1968 and that an additional 10 sets could be completed as early as September 1969.

Question 7. As relates to acute pollution levels and your organization's surveillance activities, to what extent have you attempted to develop the necessary material to forecast acute exposure levels with sufficient lead time to allow for emergency control before the fact? Has any of the work of the Environmental Science Services Administration proved useful in this endeavor?

Answer. The development of techniques to forecast the occurrence of acute pollution levels has been pursued on two scales. On the larger scale, the effect has been directed toward forecasting those areas at least as large as a 4-degree longitude-latitude rectangle where a high meteorological potential for community air pollution is expected to persist for at least 36 hours after the forecast is issued. Because of the large variation of pollutant emissions from city to city these forecasts are made specifically in terms of meteorological potential, i.e., conditions of atmospheric dispersion. These forecasts are qualitative, in that only areas of high potential are designated. A criticism of this service has been that true forecasts are not provided, since poor dispersion is already occurring when the advisories are issued. This criticism has some basis in fact, but it is mainly because atmospheric dispersion typically has a very large diurnal variation that is comparatively slow or poor at night and early morning but good during daytime. With regard to the forecast lead time for the purpose of control actions, an initial forecast of high pollution potential is made under the expectation that the meteorological situation will persist for at least 36 hours from the time issued, about noon Eastern Standard Time, which means the forecast is valid through the following day. After the initial forecast of a high pollution potential area, the forecasts are valid for 24 hours, until the next forecast is issued.

Two essential parameters in the large scale potential forecasting program are the mixing depth in the atmosphere and the transport or average wind speed through the mixing depth. Since early 1965, the National Meteorological Center (NMC) of the Weather Bureau, Environmental Science Services Administration, has been providing daily calculations and forecasts of these parameters to the National Center for Air Pollution Control in Cincinnati, Ohio. These data are specially prepared by NMC on a high speed computer; the values of these parameters are highly dependent upon other primary meteorological parameters that are forecast routinely by NMC. In this respect, it should be pointed out that the accuracy of pollution potential or pollution forecasts based on atmospheric dispersion conditions is highly dependent upon the accuracy of the basic Weather Bureau forecasts; better basic weather forecasts will result directly in better dispersion predictions. The National Center for Air Pollution Control has devoted a major effort to the determination of pollution vs. weather relationships and dispersion models. The problem of forecasting the weather features is a basic responsibility of the Weather Bureau.

On the smaller scale, research on atmospheric dispersion models is being undertaken to calculate pollutant concentrations averaged over a few hours for specific time periods of the day for Nashville, Tennessee; Cincinnati, Ohio; Washington, D.C.; Los Angeles, California; New York City; St. Louis, Missouri; and recently, Philadelphia, Pennsylvania. An ultimate purpose of this research is to utilize the models as forecasting tools. The first step in this work, however, has been to validate the applications of the dispersion models by using *observed* meteorological and pollutant data. While some progress has been achieved in this phase of the work, it cannot be described as completely successful at this time. There are several reasons for this state of affairs. First, pollutant emissions, including their temporal and spatial (vertical as well as horizontal) distributions, are known only incompletely, at best. The importance of accurate emission data in calculating pollutant concentrations cannot be overemphasized. Second, meteorological conditions over cities are not well understood because representative meteorological data in urban areas are sparse and not easily obtained. Consequently, in applying urban dispersion models the meteorological conditions must be largely inferred. A research effort is directed toward solution of this problem. A third difficulty in validating urban dispersion models is the sparsity of observed pollutant concentrations. Although pollutant concentrations are known to vary significantly at times over a city, there is no alternative to assuming that available measurements are seasonably representative. Finally, a fourth problem concerns the chemical changes that some pollutants may undergo while in the atmosphere. Because of uncertainties and complexities, meteorologists have generally avoided quantitating this problem. In view of the indicated difficulties, it is felt that significant progress has been made in developing and applying models of atmospheric dispersion over urban areas. We are optimistic that developing research will produce useful pollution forecasts for specific urban areas. On the smaller as well as the larger scales, improved accuracy of basic weather forecasts will result directly in better pollution forecasts.

(Whereupon, at 12:33 p.m., the subcommittee recessed, to reconvene at 1:30 p.m. the same day.)

AFTER RECESS

The subcommittee reconvened at 1:30 p.m., Senator Edmund S. Muskie (chairman of the subcommittee), presiding.

Senator MUSKIE. The hearing will be in order.

Our first witness this afternoon is Dr. Harry Gehm, technical director for National Council for Stream Improvement of the Pulp, Paper & Paperboard Industries.

I am sorry we did not get to you this morning.

STATEMENT OF DR. HARRY W. GEHM, TECHNICAL DIRECTOR, NATIONAL COUNCIL FOR STREAM IMPROVEMENT OF THE PULP, PAPER & PAPERBOARD INDUSTRIES; ACCOMPANIED BY ERNEST J. BOLDUC, JR., EXECUTIVE SECRETARY

Dr. GEHM. That is all right, Senator. I am glad to be here.

I. INTRODUCTION

My name is Harry W. Gehm. I am technical director of the National Council for Stream Improvement which is engaged in research and development in the fields of water and air pollution control for the pulp and paper industry.

This organization's membership currently produces over 90 percent of the Nation's pulp, paper, and paperboard. Its membership, objectives, and current activities are detailed in the accompanying 1966 annual report to the members which we are submitting for the record.[1]

I have held this position since the inception of the council 25 years ago and am a licensed professional engineer. I am testifying for the National Council for Stream Improvement at the invitation of Senator Muskie, and at the request of the American Paper Institute.

We welcome this opportunity to appear before the committee and review for you the industry's current understanding of its atmospheric emission control problems, the development of its control technology, the current state of the art and its limitations, and the industry's research and development efforts to remove these limitations.

Before summarizing our presentation, I will comment on the current status of Government-industry cooperation in this effort, together with the results that can flow from such cooperative efforts.

II. PAPER INDUSTRY EMISSION CONTROL PROBLEMS AND SOURCES

The atmospheric emission control problems of the pulp and paper industry are varied, ranging from those shared in common with all industrial and public enterprises generating steam through burning of fossil fuels, to the highly specific ones associated with the kraft pulpmills' heat and chemical recovery systems.

These systems, as you know, have proven very effective in reducing water pollution from pulping operations. Such systems separate the spent cooking liquor from the pulp in concentrated form, evaporate the liquor to high density through multiple effect and by the stack surface of evaporators and burn the liquor for recovery heat from the cookout of the wood and the chemicals for regeneration of fresh cooking liquor.

This process produces over 60 percent of the pulp tonnage and is constantly becoming a larger factor in chemical pulp production in this country. The recovery systems have been improved over the years to the point where the new systems are now close to 98 percent efficient.

---

[1] Filed with the committee.

Operation of these recovery systems is characterized by readily identified odors associated with reduced sulfur compounds, some of which exhibit odor threshold levels in the subpart per billion range. This system also gives rise to fume from salt cake employed in the process, as well as lime dust from kilns, although means for capturing these materials from the stacks to a very high degree with electrostatic precipitators and scrubbers are almost universal practice in the 98 operating kraft mills in this country.

Apart from that produced by fuel burning, sulfur dioxide lost from sulfite pulping can cause difficulties, but means for its recovery from spent liquor disposal furnace stacks, digester relief and liquor makeup system vents are provided by the larger mills. Some small sulfite mills are being dismantled because of obsolescence.

The industry trend is away from sulfite pulp. In a few years you will find that most of the small mills have been either converted to kraft or rebuilt entirely with recovery systems of their own.

Pulpmill emissions are not harmful to human health in the concentrations encountered in the ambient air. Concentrations of those gases which could be considered harmful to health, such as hydrogen sulfide and sulfur dioxide, are present at well below minimal adverse levels.

The major potential problems associated with mill emissions appear to be dusting due to the discharge of particulates that escape fuel-burning plants and high efficiency chemical recovery systems, corrosion and potential paint damage due to fumes and gases, and odors which the public finds objectionable. There are also several minor potential problems such as visibility interference which can generally be kept under control by established methods.

Of these problems, the most complicated and difficult one is odor, and because of this, it has received the most research attention by industry, Government, and university investigators.

An idea of the complexity of the problem is indicated by the fact that over 100 compounds have been associated with it and that, while the rather common industrial hygiene safety standard for hydrogen sulfide is 10 parts per million over an 8-hour exposure period, concentrations of from 0.5 to 20 parts per billion—this is billion, not million—of a number of the odorous substances, including hydrogen sulfide, can be detected by the human nose.

There is an interesting article on the constituent compounds responsible for flavors which are of course related to odors, and the flavor of coffee. It appears from this article that this relationship is so complex it has been impossible for them to identify actually what all is involved. I think we have a very similar problem with kraft mill odors.

III. DEVELOPMENT OF EXISTING CONTROL TECHNOLOGY

Existing control technology has undergone progressive development, paralleling the steady growth of the chemical pulping industry. Important landmarks along the way have been (*a*) the application of electrostatic precipitators for recovery furnace particulate emission control dating back over 30 years, and their gradual upgrading to the present, where precipitators rated above 97.5 percent efficiency are in use at 60 percent of U.S. mills, (*b*) the introduction of secondary wet

scrubbers in series with electrostatic precipitators 10 years ago, capable of removing from 50 to 80 percent of residual particulate matter, (*c*) the use since 1960 of higher pressured drop—99 percent efficient wet scrubbers on lime recovery kiln stacks, (*d*) the increasing application since 1950 of weak black liquor oxidation for hydrogen sulfide emission control, and its recent supplementing since 1960 with heavy black liquor oxidation adaptable to use in the most rapidly growing sector of the industry in the South. The reason for that is that northern weak liquor methods were not acceptable in the South because of the fatty woods that are used in that area. The species of pine found here are high in fatty materials which foam so excessively that weak liquor oxidation cannot be practiced.

They are now using heavy liquor oxidation in an increasing number of installations.

(*e*) The growing use since 1950 of thermal oxidation systems for destruction of odorous gases at locations where odor problems have been more prevalent, and other developments as well, such as demisters on the desolving tanks and hoods on the hot wells and washers which lead to external oxidation systems.

Perhaps we belabor the obvious in pointing out that these advances are the direct result of past and ongoing research and development programs conducted or supported by the industry, associated research institutions and process equipment suppliers.

These accomplishments lead us to hold out hope that our remaining problems will yield to sustained attack on an organized fashion.

IV. CAPABILITIES AND LIMITATIONS OF PRESENT STATE-OF-THE-ART

Our present technology is capable of mastering particulate emissions and, where ambient air quality programs so require, reducing such emission levels from recovery furnaces and lime kilns to 0.05 grains per cubic foot.

We are, however, not certain that optimal methods have yet been developed to accomplish such objectives, and alternate technology is being evaluated to determine whether it may prove advantageous. Some odorous emission sources of limited volume lend themselves to thermal oxidation, and the primary hydrogen sulfide source is controllable through black liquor oxidation and the most advanced recovery furnace design and control procedures.

Elevated single stacks have permitted some mills to make use of more favorable atmospheric dispersion processes, but their limited capabilities in regions involving multiple emission sources are recognized.

The answer to the matter of tall stacks is that in some places they work, others they don't, and I think in considering individual installations we have to make selections of those control measures which are best for the atmospheric conditions and the other factors with which we have to deal.

The principal limitation in our current state of the art lies in elimination of mixed reduced sulfur compound odors from large volume recovery furnace stack gases. This area is increasingly becoming the focus of our research and development efforts.

V. CURRENT INDUSTRY RESEARCH AND DEVELOPMENT PROGRAMS—THEIR OBJECTIVES AND EXTENT

By far the bulk of the industry's research and development program is currently being conducted at the individual company level, with only a modest portion conducted through industry organizations. One should not overlook the additional contributions to this program by the industry's major process equipment suppliers.

A. National Council—An organization program in this area was first authorized by the National Council in 1956 as an adjunct to the stream improvement research program, and funded initially of $50,000 annually.

This modest program has been gradually increased to a $100,000 annual budget, and plans are being considered now for a substantial expansion of this program.

Its objectives are to aid in (1) finding new means to reduce overall losses from pulp and papermill stacks of particulate and gaseous substances, and minimizing objectionable odors, (2) providing the industry with the best techniques for sampling and monitoring process emissions and ambient air to advance problem definition, and evaluation of control process performance, and (3) optimizing the selection and use of control technology for solution of specific problems by the industry by constantly evaluating the current state of the art.

An important feature of this program is the broad and frequent dissemination of technical information throughout the industry by means of technical bulletins and meetings.

Since the inception of this program we have published about 35 technicals in this field and in addition a number of surveys and things dealing with such things as industry practice and research and our monitoring procedures.

Since 1956, research projects have been centered in the Southeast and the Pacific Northwest in close proximity with major concentrations of the kraft pulp industry.

Currently these projects are located at two of our regional research centers, in the Division of Engineering Research at Oregon State University, and in the Department of Bioenvironmental Engineering at the University of Florida, and are involved in a variety of investigations, which are summarized for the record in attachement No. 2 (National Council for Stream Improvement—Atmospheric Pollution Research and Development Program—1967), which is part of the record.

The history of our program's development and scope is detailed for the record in attachment No. 3 (Technical Bulletin No. 29, "Status of Present Investigations and Future Research Needs in Atmospheric Pollution Control," June 1966).

The major stress at both centers is on stimulating improvements in analytical capabilities, and laboratory and field studies of new technological approaches to emission control.

B. Paper industry programs: The industry's current commitment to research and development aimed at advancing the current state-of-the-art is best illustrated by our recent findings that annual research and development expenditures between 1963 and 1966 averaged $850,-

000, and that budgeted expenditures for 1967 rose by 130 percent to $1,950,000.

The amount of professional effort involved in such work rose similarly by 120 percent.

The main objectives in these company programs have paralleled those of our program and include (1) identification of emission sources and levels and their variability, (2) improvements in analytical, monitoring, and process control capabilities, and (3) development and evaluation of new emission control approaches.

Again, the stress in the search for new control technology is on perfecting our particulate emission control capability and finding major advances in odor emission control. Mention should also be made of regionally supported research and development programs such as those supported by the Northwest Pulp & Paper Association, which are cooperated in by us, and the Pulp Manufacturers' Research League, which have similar objectives.

C. NCSI-Industry program review: We are currently going through a period of intensive review within the industry and the national council of our total efforts in air pollution control.

A major portion of this review relates to the direction which our joint and independent research and development programs will take for the next few years.

It has become clear to us during this review that the major problem for which we are seeking solutions; namely, adequate control and elimination of kraft odor emission, is an exceedingly complex one.

Its complexity stems from the fact that kraft pulping involves the integration of several major unit processes, the handling and discharge of large gaseous emission volumes, the efficient recycle of several hundred pounds of reduced sulfur compounds per ton of pulp produced yielding low residual concentrations of these compounds in our gaseous emissions with extremely high odor threshold levels. I feel that the scientific and technological challenges facing us are substantial.

Here, of course, we run into the law of diminishing returns, and to get 99 percent of it out requires x number of dollars to get 99.9 percent $3x$ number of dollars.

During this review, there has been accelerated information sharing and comparison of program objectives to increase the likelihood that major advances will result from these programs.

Our own staff recently completed a 3-day meeting with a panel of pulp industry experts to assist in planning a major intensification of our total efforts, and a significant expansion of the council's program for 1967–69.

VI. GOVERNMENT-INDUSTRY COOPERATION IN RESEARCH AND DEVELOPMENT EFFORTS

I would like to comment on three specific areas and activities where such cooperation has, and will in the future prove of value in advancing our state-of-the-art.

A. PHS support of kraft-related projects: I am pleased to see in the last two research grant listings for fiscal years 1966 and 1967,

issued by PHS-National Center for Air Pollution Control, that kraft industry-related research projects are being supported to the extent of $150,000 annually in a variety of worthwhile areas.

This is a reflection of the Government's willingness to assist in the search for solutions to our outstanding problems, particularly of odor control.

It is also a sign of a growing interest and capability in the scientific community in research toward this goal.

I should also add that a great deal of the PHS-supported research in such important general areas as analytical methods, particulate behavior, and instrumentation have proved of great value to industry's efforts.

B. International Research Conference on Kraft Industry Emissions: In April 1966, an international conference on atmospheric emissions from the kraft pulping industry was held at Sanibel Island, Fla., under the joint sponsorship of the University of Florida, the Public Health Service, and the National Council for Stream Improvement.

The purposes of this meeting were (1) to summarize current knowledge regarding the sources, effects, and control of kraft pulp mill emissions, and (2) identify current research needs in this area.

The conference was attended by 47 invited participants drawn from industry, government, academic research, and equipment suppliers both here and abroad. The whole range of emission problems received an extensive airing of great benefit to all the participants.

We expect the proceedings to be available shortly, and have attached to our statement some pertinent details for the record concerning the conference. (See attachments No. 4 and No. 5.)

At the conclusion of the formal presentations, a summary committee consisting of members of three sponsoring groups including Mr. Austin Heller, then with Public Health Service, and now in charge of New York City's program; Dr. Charles Spaulding of the University of Florida, and Dr. Isaiah Gellman of NCSI, prepared a listing of research needs drawn from the papers presented.

This listing included the following:

1. Improve identification of air pollution effects.
2. Develop new and improved analytical techniques.
3. Study in detail recovery furnace odor emission prevention and control.
4. Develop improved methods of black liquor oxidation relative to emission control.
5. Improve present methods for handling evaporator and smelt dissolving tank gases.
6. Compare losses from different calcining devices.
7. Continue studies of the pulping process relative to odor control.
8. Carry on specialized meteorological studies.

The industry reaction to the recommendations, particularly those taking a direct approach toward reduction or elimination of emissions was most favorable.

It was felt by many that those regarding epidemiological studies, socioeconomic impact and organoleptic techniques were of secondary priority from the standpoint of placing industry research funds to produce positive results for solving recognized problems.

We have taken full cognizance of the ideas expressed at the Sanibel

Island Conference in our current activities, and in our efforts to develop a program for the next few years.

C. Proposed cooperative PHS–NCSI study: We are currently completing planning of a joint study between PHS and NCSI which will result in production of an extensive technical manual on paper industry emission sources and available control technology.

This activity should prove valuable in familiarizing control agency personnel nationally with the character of our emissions and the means now available to cope with them.

We expect also, that further research guidance will stem from this activity.

VII. SUMMARY

The industry effort with respect to development, installing and testing new techniques leading to reduced emissions, is increasing rapidly as evidenced by some of the advanced practice built into new mills and added to some older installations.

Serious action problems exist in respect to older mills resulting from space limitations, piping, access problems, and the generally lower efficiency of the older major equipment.

This, too, is an area where haste must best be made carefully, because of lack of knowledge relative to the ultimate effect of in-process changes on emissions and particularly the ambient air.

It is hoped that a considerable portion of the research dollar of the future will be apportioned to such evaluation. This applies particularly to the matter of odor which is enormously complex and a most difficult area in which to measure up to public expectations largely because of the law of diminishing returns, meteorological factors and frequently, geographical location.

The industry appreciates the need for additional research and development work in air pollution and is in the process of increasing materially both its individual efforts and joint endeavor with government.

It is favorable to the direct approach leading to reduction or elimination of emissions rather than the investigation of abstract or theoretical side issues, since this is unquestionably an area where large sums of money could readily be expended without leading to much forward progress.

Hence, in this costly area, prudent and carefully planned research and development programs only should be selected for support.

A progressively effective research and development program in air pollution control by the pulp and paper industry requires an integrated program to which the industry, government, major equipment suppliers, instrument specialists, and operations personnel all contribute their part.

The activities enumerated and described in this presentation all indicate that such an approach is rapidly developing.

I am happy to be here, Senator, and I will be glad to at least attempt to answer any questions that you may have.

Senator MUSKIE. Dr. Gehm, in your statement you say that:

> The major potential problems associated with mill emissions appear to be dusting due to the discharge of particulates that escape fuel burning plants and high efficiency chemical recovery systems, corrosion and paint damage due to fumes and gases and odors * * *.

You indicate, I think, the most difficult and complicated problems. Do the others have any consequence anywhere?

Dr. GEHM. Yes; they can, depending on circumstances where even high degrees of recovery are not sufficient, where you have serious inversions and where we deal with older equipment which is not as efficient as the new systems.

Senator MUSKIE. Particulates from the fuel burning plants depend upon the fuel being used?

Dr. GEHM. The rules there apply the same as they do to utilities, Senator.

Senator MUSKIE. I see.

Dr. GEHM. We deal ourselves mainly with pulp production and recovery processes rather than with fuel burning, although we have a bulletin dealing with fuel burning which was prepared to assist the mills in handling that problem.

Senator MUSKIE. Is paint associated with the older problem?

Dr. GEHM. Yes and no. It can be or it cannot. For example, relatively nonodorous fumes can cause corrosion and some odorous sulfur compounds can cause paint darkening.

Senator MUSKIE. Does the technology that is available for a new plant represent any progress with respect to any of these pollutants that you have mentioned?

Dr. GEHM. Yes; I think they represent by measurement very considerable progress.

Senator MUSKIE. Could you give us some idea?

Dr. GEHM. The results at times have been disappointing largely from the standpoint of odor. As long as the public smells the odor, they feel that nothing has been done. However, the new mills are vastly improved over the old mills in regard to emissions.

Senator MUSKIE. Can you give us any quantitative indication of that improvement?

Dr. GEHN. Well, I would say that a new mill runs up to as high as 99 percent recovery on the basis of the measurements we use.

Senator MUSKIE. In my State, we have four or five kraft mills. Some of them are older than others. Is there a difference among those five mills with respect to the control? I know it is not easy to detect it with your nose. Is there a quantitative difference that is meaningful?

Dr. GEHM. I would assume there would be because of the differences in the time at installation but I am not personally acquainted well enough with the specific projects, Senator, to pass on that. Some of our people do, but I have not seen them recently enough to make comparisons.

Senator MUSKIE. What is the nature of the control mechanism or the control process that has been used to reduce the odor problem thus far?

Dr. GEHM. Processes used have been electrostatic precipitators and in some cases secondary scrubbing beyond these. These are effective to some degree from the odor standpoint since the fumes are inclined to absorb the odors.

Senator MUSKIE. Has an effort been made to attack the particulate problem?

Dr. GEHM. The combustion of the noncondensable gases—the relief, blow gases and evaporator gases, reduce the overall odor problem, but not the particulate emissions.

Scrubbers on the lime kilns reduce the loss of lime and fumes from those. Columns or demisters on dissolving tanks which trap fumes from those units as well as the oxidation of the black liquor prior to final evaporation and burning are inclined to reduce odors from the stack. They can eliminate hydrogen sulfide almost completely from the recovery stack.

Senator MUSKIE. Is there any prospect that the odor can be eliminated altogether?

Dr. GEHM. I am rather doubtful myself that it can—that is, altogether. To eliminate it entirely—small leaks and other things that are bound to occur would prevent this degree of perfection. I think there is a reasonable hope that new measures are bound to reduce to a very high degree so that detection will not be widespread.

Senator MUSKIE. Is there any possibility of developing an alternative process to develop the same product?

Dr. GEHM. I know companies that are working on it and not being a pulp technologist, I would be reluctant to comment on their chances of success. I know that there is considerable work going on but something must be considered there. It is like attempting to replace gasoline-driven cars with electric-driven. Here we have, over a hundred large kraft mills, representing tremendous investments in this system. It is questionable whether these would be abandoned or converted to another system in a relatively short period of time.

Senator MUSKIE. Is the kraft mill the result of the conversion from mechanical grinding of woods to chemical reduction of them?

Dr. GEHM. No; it has come along as a complete chemical pulp to replace sulfite pulp to a great degree because of the wider species of woods the process can handle. The kraft process is responsible for the growth of the pulp industry in the South since it can employ the fatty woods of the South for producing a wide variety of products.

Almost any type of pulp can be produced through this process plus the added economic advantages of chemical and the heat recovery system.

On the other hand, it is an extremely high initial investment proposition since the recovery plant can cost practically double the pulp mill.

Senator MUSKIE. Can you give us any idea of the costs that are involved and the technology of odor control?

Dr. GEHM. I am rather reluctant because of individual mill differences and not being too closely associated with the economics of the processing not being involved in day-to-day operations and engineering.

Senator MUSKIE. Could you give us for the record anything that would give us some idea of the order of magnitude this involves? Would you consult with your people on that?

Dr. GEHM. We could do that; yes. I would prefer that very much.

Senator MUSKIE. We would like to get some idea.

Mr. BOLDUC. Yes. We will reply to that question, Senator.

Senator MUSKIE. You have not commented upon the legislation. I assume that you consider that was covered in the earlier testimony?

Mr. BOLDUC. We felt that our instructions were to relate our testimony to existing technology and research needs.

Senator MUSKIE. What you are saying here this afternoon is that

there is not at the moment technology available to deal with the odor problem in the kraft process mill.

Mr. BOLDUC. That is right.

Senator MUSKIE. So you don't even get to the question of reasonable economics.

Dr. GEHM. Well, I thought you meant economics in terms of what we can do now to lessen the problem.

Senator MUSKIE. There is a difference in performance between the older mills and the newer ones. Now, how much of a problem would it be to require the older mills to meet at least the performance of the newer mills?

Dr. GEHM. I am afraid it would be extremely excessive because of the problems I have pointed out in my testimony.

First, there is the large capital equipment of lesser efficiency in the older mills. They have to be replaced entirely since they can't be readily revamped to reach anything like the efficiency of the new mills.

I made some remarks here about the problems of execution of the old mill, too, of piping and space problems and the rest. It would be different for every unit.

Senator MUSKIE. Could you submit for the record at least an illustrative situation to give us some idea of the order of magnitude of the numbers involved in improving the performance of the older plants to meet the performance of the newer ones?

In other words, how fast can you take advantage of developing technology? How much is it going to cost? We got into this question in a general way somewhat this morning.

Now, I would like, wherever we can, to illustrate the points we are trying to raise from actual situations.

Mr. BOLDUC. In other words, you would like us to respond to the order of magnitude with the idea of improving these older mills to new mill standards, if that could be done?

Senator MUSKIE. Yes; some specifics of what would have to be done in terms of new equipment, equipment replacement, and equipment improvement and any other changes in the processing or equipment of an older mill to bring it up to date.

(Subsequently Dr. Gehm submitted the following communication in response to the foregoing questions:)

NATIONAL COUNCIL FOR STREAM IMPROVEMENT
(OF THE PULP, PAPER AND PAPERBOARD INDUSTRIES), INC.,
New York, N.Y., June 1, 1967.

Mr. RICHARD B. ROYCE,
Chief Clerk and Staff Director,
United States Senate, Committee on Public Works,
Washington, D.C.

DEAR MR. ROYCE: During our testimony at the May 15 hearing on current status of research and development efforts in air pollution control and abatement, Senator Muskie requested that I furnish him with a figure for the cost of reducing kraft pulp mill emissions to the highest degree possible with currently available technology.

These measures would include the following:

1. Installation of a highest-known efficiency electrostatic precipitator on the kraft recovery furnace, followed by a secondary scrubber.
2. Installation of a high-efficiency particulate collection system on fuel-fired power boilers where fuels producing fly ash are in use.
3. Construction of an elevated stack, serving both the recovery furnace and power boiler (including interconnecting ductwork) to provide maximum dispersion of residual particulate emission.

4. Installation of a high-efficiency wet scrubber on the lime recovery kiln stack.

5. Installation of demisters and associated scrubbing devices on the recovery process smelt dissolving tank vent stack.

6. Collection of all digester relief and blow gases for heat recovery, and combustion or oxidation of residual non-condensible gases together with those from multiple effect evaporators.

7. Installation of a high-efficiency black liquor oxidation system.

Our estimate of the installed cost of providing these measures for a new 500 ton per day kraft mill is approximately between $1,500,000 and $2,000,000.

Relative to Senator Muskie's question concerning the cost of improving an old mill solely from the emission standpoint in comparison to costs incurred during initial construction of a new mill, we feel this question can only be answered in general terms. We have already pointed out that serious construction and process problems arise in such cases resulting from space limitations, piping and access problems, the multiplicity of process units, generally lower efficiency of older equipment, and the added cost burden of premature retirement of control devices no longer providing adequate emission control. Such costs are therefore of necessity higher than for a new mill, and the difference in costs can only be determined on a case-by-case basis.

Older mills frequently undergo extensive, but partial, renovation, during which smaller, multiple, major process emission source units (i.e. recovery furnaces, evaporators and digesters) and associate emission control devices (i.e. electrostatic precipitators) are actually replaced, often with single units of considerably higher capacity. For example, in a recent instance, three old 200 ton per day recovery furnaces and their associated precipitators were retired and replaced with a single 1,000 ton per day modern furnace, equipped with a very high efficiency electrostatic precipitator.

These new recovery furnaces are built and operated so that resultant emissions carry lower concentrations of the major constituents, and are less odorous than those emissions produced by older furnaces since (a) combustion conditions are improved; (b) more effective air distribution leads to additional destruction of odorous substances in the exhaust gases, and (c) the newer furnaces are ducted so as to more readily accommodate higher efficiency precipitators. These precipitators also remove more odorous substances on the precipitated dust since it has been demonstrated that some reduced sulfur compounds are present, probably by surface adsorption, in the separated dust. Many mills have also replaced old batch digesters with larger and fewer continuous digesters during such renovations. These digesters reduce the loss of non-condensible gas and surges in gas volume, thereby simplifying their further treatment.

I hope the above information fills the additional needs expressed by Senator Muskie during my testimony, and wish to again express our thanks for the opportunity to assist the Committee with our testimony. We are also sending, under separate cover and for your file, five (5) copies of the Chemical & Engineering News special report, "The Chemistry of Flavor", which I referred to in my testimony as illustrative of the scientific complexity of odor characterization.

Very truly yours,

HARRY W. GEHM, *Technical Director.*

Senator MUSKIE. While you are on this subject, you might also give us some idea of the degree to which you might improve performance in line with normal replacement of obsolescence; the equipment does wear out and have to be replaced. What are the prospects for upgrading its performance in the course of that process, and how much time would be involved?

Dr. GEHM. That is a much easier question to answer because it is being done throughout the industry, old plants being refurbished and being rebuilt. Economically, it is sensible to employ the high efficiency equipment in such cases.

Senator MUSKIE. Now, we have touched on odor particularly.

Is there a technological obstacle to the control of particulates now?

Dr. GEHM. Not to reasonable control; no. I think it is almost universal practice with the industry.

Senator MUSKIE. Percentagewise?

Dr. GEHM. I am speaking now of a large percentage having over 95 percent efficiency.

Senator MUSKIE. Over 95 percent?

Dr. GEHM. Yes.

Senator MUSKIE. What is the control mechanism, the electrostatic precipitators?

Dr. GEHM. Electrostatic precipitators and scrubbers.

Senator MUSKIE. Are those pretty much routine equipment now on new plants that are constructed?

Dr. GEHM. All new plants have them; practically all the old plants have them. It is largely a question of degree, but there is no plant, to my knowledge, without scrubbing or electrostatic precipitators.

Senator MUSKIE. Now, if you get that kind of performance, do you still get complaints on this? If you are getting 95 percent performance on your electrostatic precipitators, do you still get complaints on your charge of particulates?

Dr. GEHM. I think that the particulate complaints are declining to a great degree. Odor complaints seems to be taking its place.

Senator MUSKIE. The paint damage, in my experience in Maine, and I suppose corrosion, too, is associated with odors from the water pollution, in part.

Dr. GEHM. They can be but generally if you have no water pollution odors, you can have these problems from stack emissions.

However, the change in the composition of the paints from lead to other pigments have largely eliminated the paint damage problem. I think the one that suffers worse from corrosion is the mill itself, because the large part of the total particulate fallout occurs in the mill yard itself.

Senator MUSKIE. Here I take it you have made some improvements but you still have a large bulk.

Dr. GEHM. The odor is the worst problem, sir.

Senator MUSKIE. Under Senator Randolph's amendment No. 181, especially that relating to research, does your industry have a view relevant to the patents which may develop under joint Government-industry research projects?

Dr. GEHM. We have not been involved with Government in research and development but as far as our organization is concerned, which is the only one I can speak for really, the few patents we obtained are only for protection of the industry and can be considered public property since we make them available on a royalty-free basis.

Mr. BOLDUC. They are dedicated to the public and this policy was reaffirmed at a recent meeting of our board, so our patents are open to all.

Dr. GEHM. I think that is quite true of a number of the large companies that have made advances in air pollution control. They have made their patents generally available.

Senator MUSKIE. All right.

Thank you very much, Doctor.

The attachments to your prepared statement, with the exception to No. 1, will be placed in the record at this point.

Dr. GEHM. Thank you, Senator.

(Attachments 2, 3, 4, and 5 referred to are as follows:)

ATTACHMENT NO. 2

NATIONAL COUNCIL FOR STREAM IMPROVEMENT'S RESEARCH AND DEVELOPMENT PROGRAM—1967

ULTIMATE OBJECTIVES

To find means for reducing the discharge of particulates, fumes and undesirable gases from pulp and paper mill stacks and reduce, as far as possible undesirable odors. To provide industry with sound evaluations of process changes and installations on stack losses and ambient air quality and provide the best techniques for monitoring and relating performance to regulations.

LABORATORY PROJECTS

(1) Thermal destruction of kraft pulp mill off-gases.
(2) Secondary scrubbing of recovery furnace stacks.
(3) Oxidation of odorous compounds resulting from kraft pulping.
(4) Preparation of an updated manual of sampling and analytical techniques for both stack and aerial surveys.
(5) Use of the Flame Photometric Detector in gas chromatography.
(6) Determine absorption efficiency in wet analytical methods as employed in the analysis for sulfur compounds.

DEVELOPMENT PROJECTS

(1) The use of molecular oxygen in BLO.
(2) Application of the recording chromatograph in recovery furnace operation.
(3) Determination of the effectiveness of BLO in reducing sulfur losses and assembly of basic design data for its installation.
(4) Determination of loss of sulfur compounds from continuous kraft digesters and their removal or recovery from the off-gas streams.

SURVEYS

(1) A continuing review of installations designed to reduce stack losses within the kraft industry.
(2) A survey of sulfur dioxide losses from sulfite pulping and industry practice in reducing them.
(3) A survey of research and development expenditure for air pollution control by individual kraft pulp producers.
(4) A survey of fossil fuel burning within the industry.
(5) Preparation of a "Manual of Practice" in the kraft pulping industry in cooperation with the USPHS.

ATTACHMENT NO. 3

STATUS OF PRESENT INVESTIGATIONS AND FUTURE RESEARCH NEEDS IN ATMOSPHERIC POLLUTION CONTROL

A—INTRODUCTION

In February 1956, following an initial recommendation by West Coast mills and general discussions over a two-year period, the Board of Governors agreed that the National Council should undertake research and development in the field of air pollution control. It was recommended that this activity be carried on as a special project and financed separately. National Council members, at their own option, were eligible to join in this activity on payment of an additional assessment earmarked for it. Sufficient support to get started was quickly obtained and the first project got under way at the University of Florida in July of the same year. In the interim, the Council staff assembled a bibliography and library on the subject in the New York office.

The first project to get under way, was the University of Florida in July 1956. This was headed by Dr. E. R. Hendrickson, a specialist in the atmospheric pollution field, and nationally known through his activities with phosphate industry problems. He has since served as Chairman of the Florida Air

Pollution Control Commission for several years, and as national president of the Air Pollution Control Association. Dr. Hendrickson was assisted on our project by Admiral A. L. Danis, an eminent meteorologist.

The following tasks were included in the project:

(1) To summarize the general principles of meteorology as they apply to air pollution and its control by pulp and papermills and show how they could be applied in assessing and combating the problem. Also included was the task of setting forth the technique for collection and tabulation of such information so that it could be of maximum value.

(2) To develop as simple and applicable techniques as possible for measuring flow, sampling, and analysing kraft mill and other pulp and papermill mill stack effluents.

A second project was initiated in April 1957 at Washington State University under Prof. Donald Adams. This department was selected because of its northwestern location, an area where air pollution control was very active, and the competence of this research group in the new analytical tool, gas chromatography.

The purpose of this project was to:

(1) Develop gas chromatography techniques for identification and measurement of the compounds responsible for the odor of kraft stack effluents.

(2) Use these techniques to survey the kraft mills in the northwest to determine the discharge level of the major odorous compounds from the various emission sources.

(3) Determine the effectiveness of chlorine oxidation on the major odor sources, mercaptans and sulfides.

(4) Develop gas chromatography techniques suitable for continuous measurement of odorous sulfur compounds for adaptation in mill operating control applications.

A year later in 1958, an additional project was instituted at New York University under Dr. William Ingraham. This University has been a leader in the field of air pollution resulting from particulate matter, having been employed by a number of large power companies for many years. The job assigned to this project was to prepare a manual dealing with air pollution resulting from fuel combustion. This work was accomplished in a little over one year, and a manual covering legislation, regulations, methods of measurement, combustion control, stack-cleansing techniques and stack-height determination was published as Air Technical Bulletin No. 12.

From 1959 to 1963, Rutgers University conducted specialized studies on aerial sampling and analysis—particularly with regard to hydrogen sulfide and its effect on painted surfaces. Through coordination of knowledge provided by this project and the University of Florida achieved by Dr. N. J. Lardièri of the staff, the methods of aerial survey now recommended by the Council and employed by a number of mills were developed.

The Operating Committee has directed that, insofar as possible, the air pollution control program be integrated with the five National Council Research Centers. The first moves made in this direction were to obtain personnel at Louisiana and Oregon State Universities to start a program. Council research activities at these centers have been largely directed toward laboratory and field studies dealing with methods for reducing kraft mill odors, which appear to be the major immediate problem that cannot be solved with existing techniques. Naturally, attending problems have and will receive further attention.

The body of this report consists of a staff review of progress and the current status of research and technical programs in the following areas:

(1) Analytical methods for source-gas sampling and gas-flow measurement.
(2) Black liquor oxidation.
(3) Absorption and oxidation of sulfur compounds.
(4) Particulate emission control.
(5) Meteorology and ambient-air-sampling techniques.
(6) Cooperative mill service activities.
(7) Staff technical activities.

Further details are available by reference to the 28 technical bulletins published since inception of the program. The report concludes with a staff appraisal of identified research needs for the foreseeable future.

B—REVIEW AND CURRENT STATUS OF AIR POLLUTION RESEARCH PROGRAM

1. Analytical methods for source-gas sampling and gas-flow measurement

To evaluate the effect of kraft mill emissions on surrounding areas it was necessary to develop adequate source-sampling and analytical techniques. The first step was a review of the literature on methods of analysis, which subsequently was published in two technical bulletins. The Council then developed and published a wet analytical method for sulfur compounds. Field experience indicated that a major limitation of this method was the determination of total sulfur by combustion to sulfur dioxide. Too high a degree of control was required in this step.

Since the assessment of total sulfur is useful in obtaining a loss balance on a kraft mill, the wet analytical method was modified to collect and measure the four major sulfur compounds present in the airborne effluents (hydrogen sulfide, methyl mercaptan, dimethyl sulfide, and sulfur dioxide). A further modification, designed as a check on the total sulfur measured as individual components, involves thermal oxidation to sulfur trioxide, followed by chemical oxidation by hydrogen peroxide, and has eliminated the earlier limitation.

The analysis for individual components has been used to evaluate critically odor control processes, and has clearly pointed up some inadequacies of these processes. The use of these sampling and analytical techniques in the field, has provided data supporting many of the theories about furnace operation, the problems caused by contact evaporation, and the question of sources of sulfur emissions in a mill. The usefulness of these developed analytical methods in determining emission levels was illustrated in the summary of three years of evaluations presented at our last annual meeting. Development of newer instrumental analytical methods, specifically gas chromatography, suggests eventual replacement of the wet methods by such instruments. Figure 1 shows a gas chromatograph used in our research and development program at Louisiana State University. Very briefly, this is a device which partitions an unknown gas mixture on the basis of physical or chemical characteristics of its constituents.

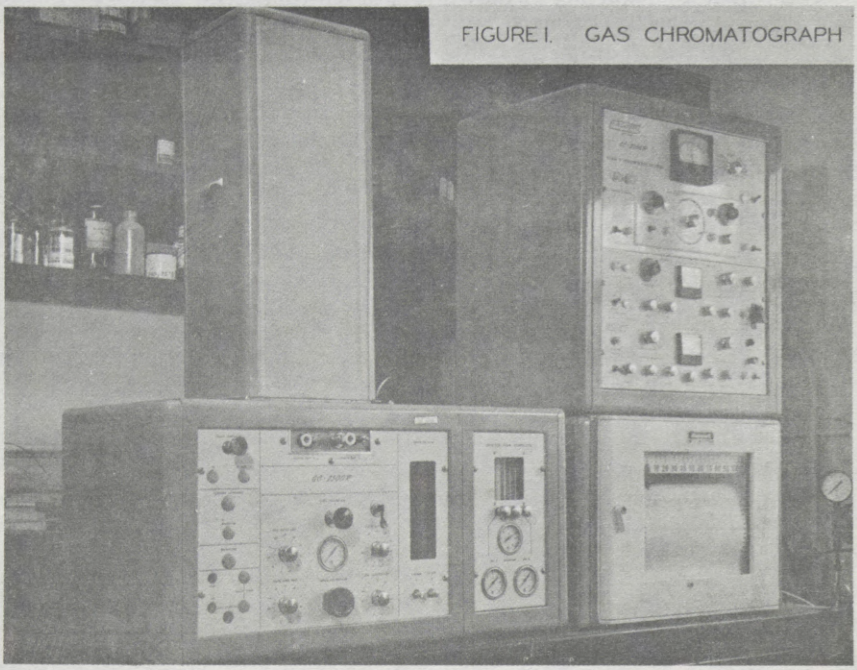


FIGURE I. GAS CHROMATOGRAPH

In the early application of gas chromatography, the instruments lacked sensitivity. Even for stack gas analysis, the samples had to be concentrated before successful partition could be effected and measured. Therefore, the Council initiated research toward the development of more effective techniques for gas chroma-

tography. As new and more sensitive detector systems were developed, they were evaluated on the compounds common to kraft pulping. To date, the most promising chromatographic development is the micro-coulometric detector. This instrument is sensitive to 1 ppm of sulfur compounds. Therefore it appears that source sampling using this detector may require only a grab sample at the stack, followed by analysis in the mill laboratory. Several mills are now using gas chromatographs, and others are contemplating their use for routine testing and eventually continuous monitoring.

2. Black liquor oxidation

Black liquor oxidation has been practiced in the kraft industry for a number of years, and its value in the control of hydrogen sulfide in the recovery furnace stack has been well demonstrated. Excessive foaming is encountered when black liquor oxidation is attempted on weak black liquor from the pulping of resinous woods. Considerable research effort has been spent toward developing means of controlling such foam chemically, mechanically, thermally, and sonically without much success. Investigations, however, showed that concentrated black liquor high in soaps could be successfully oxidized without severe foaming.

The Pasadena, Texas, mill of Champion Papers had been oxidizing concentrated black liquor for two years when they reported their results at the Council's 1962 Annual Meeting. Since that date, ten large, heavy black liquor oxidation units have been either installed or planned. The Council acted as liaison between interested mills for the dissemination of information pertinent to the adaptation of the Champion system. Without this cooperation between member companies and the National Council, it is doubtful that concentrated black liquor oxidation would be as widespread today, and it may very well have been more costly for each mill to develop its own oxidizing system.

Along with the dissemination of design information, the Council also evaluated the effect of oxidation at various mills employing black liquor oxidation. Better than 90 percent reduction of H_2S was shown to be effected on all tested furnaces which did not exhibit excessive losses from the firing zone. The benefits of black liquor oxidation with respect to ambient sulfide levels were shown in the results of a 2-year testing program conducted by a member mill with the cooperation of the National Council. The curves shown in Figure 2 indicate the rate of decrease of sulfides at various distances from the mill when half and all the black liquor were oxidized.

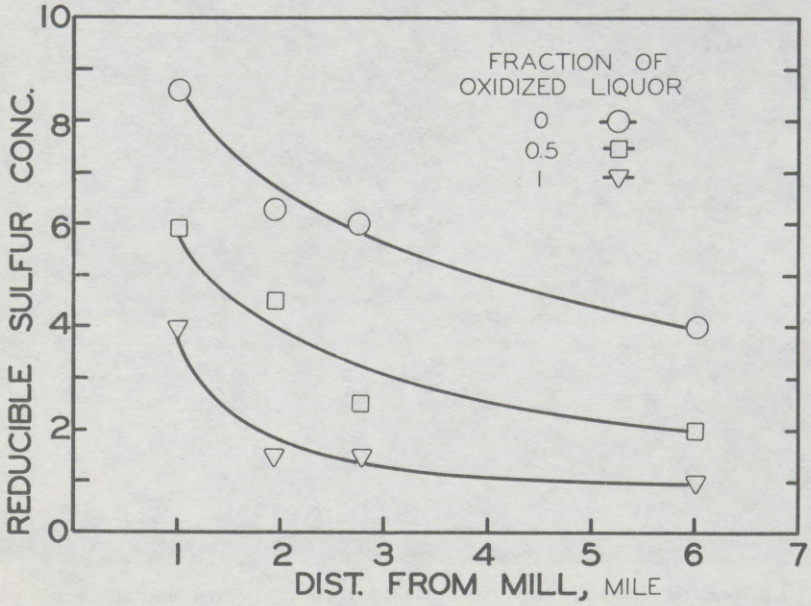


FIG. 2. EFFECTS OF BLACK LIQUOR OXIDATION ON REDUCIBLE SULFUR GASES

Although uncontrolled foam was a serious problem in attempting weak black liquor oxidation, some laboratory mass transfer devices which were designed to minimize foam were evaluated. This research was described in Technical Bulletin No. 165. Fundamental absorption rates were measured at low turbulence in thin film devices which were successful in controlling foam. These, however, were found to be impractical since too much surface area was required for effective oxidation. In a recent study, the foaming tendency of weak black liquor has been put to some use in a proposed foam fractionation process to increase soap yields.

3. Absorption and oxidation of sulfur compounds

To determine whether any alternative to burning odorous gases for their ultimate destruction might be feasible, methods for absorption and chemical oxidation came under investigation. Chemical streams inherent in the kraft process, such as chlorine bleach effluents and dilute caustic solutions, were obvious possibilities, since this chemical is effective in absorping H_2S and methyl mercaptan. Laboratory and field studies have shown that the absorption rate is dependent on the pH of the scrubbing solution, a stream with a pH of less than 11.0 being no more effective than plain water. With the use of streams of pH near 14.0, the absorption rate can increase 20 to 30-fold. The effectiveness of an existing scrubber is increased accordingly. The use of caustic in scrubbing mercaptans is of limited odor control value due to the formation of odorous disulfides in the presence of oxygen. These reaction products will be stripped out of the exhausted scrubbing liquor unless handled in a closed system.

The use of chlorine in acid and alkaline solutions has been studied and found to be effective in the oxidation of H_2S, methyl mercaptain, and dimethyl sulfide. In acid media, reaction is slow, but a stable, innocuous end product results. Reaction of reduced S compounds with chlorine at alkaline pH levels was shown to be more rapid. However, methyl disulfide, an insoluble, odorous compound is formed by partial oxidation and stripped out of solution. Field evaluation of existing odor control scrubbers is currently under way, and the findings will be summarized in a technical bulletin to be distributed shortly.

Fundamental studies on other chemical oxidants and oxidation catalysts have been initiated and will be extended as benefits are shown.

4. Particulate emission control

Previousily, reference was made to the work of Dr. Ingraham in preparation of the material for Technical Bulletin No. 12. It suffices to say that this comprehensive review illustrates that the air pollution problem associated with fuel burning and related to particulate discharge from such a cause, is usually amenable to reasonably precise definition and solution.

This is in contrast to the knowledge that has been available on reducing particulate emissions from recovery furnaces beyond that achieved in conventional control devices. The Council's West Coast Research Center has been active in this area since initiation of air pollution program at Oregon State. Interest in this area stemmed from the need of local mills to comply with existing ambient air quality requirements for particulate matter. After cooperation with two mills on pilot studies of secondary scrubbers behind the primary recovery units, an evaluation of field installations was initiated. Seven such units now exist or are under construction, handling flows of from 60,000 to 450,000 cfm. The objectives of this survey are set forth below:

(1) To determine effectiveness on particulate discharge control.

(2) To determine energy and water requirements for scrubbing.

(3) To compile corrosion problems involved and determine suitability of promising materials of construction.

The effectiveness of particulate control is being measured by stack sampling, and in most cases can be correlated with ambient-air survey data collected prior to scrubber installation. Energy and water requirements are related both to the economics of operation as well as efficiency. Due to high corrosion rates in early scrubber installations, the suitability of more resistant materials now in use, such as tile and fiberglass, as materials of construction are being documented.

Stack survey and ambient air data confirm that these devices are capable of reducing salt cake fallout in the mill vicinity to a minimum, well within existing ambient air quality requirements. They are also capable of meeting the most rigorous source emission regulations now in force. These devices are not, however,

effective in reducing gaseous sulfur emissions unless the pH of the scrubbing solution is above 11. Pilot and one full-scale field investigation has shown that 80 per cent of H_2S in relatively high concentration are removed with caustic use amounting to approximately 125 lb/ton pulp produced.

5. Meteorology and ambient air sampling techniques

A significant part of the Council's effort in air pollution work has been related to means of defining the conditions that can, or do, exist in the ambient air surrounding mill environs. Those areas of principal interest where work has been done and technical bulletins have been issued are listed below:

(1) Meteorology.
(2) H_2S tile study.
(3) Techniques for high-volume sampling.
(4) Methods for conducting ambient air surveys.

The application of techniques for collecting and tabulating meteorological data set forth have constituted the basis for several sampling programs either now in existence or since terminated.

There is a need for continuous monitoring of H_2S in some areas and work was undertaken to evaluate the simple lead acetate tile technique for this use. The research showed that uncontrollable environmental factors limit the effectiveness of the method as a quantitative analytical tool.

A recent bulletin describes sampling and analytical techniques for measuring suspended particulates in the atmosphere. This permits interested mills to collect information and compare local conditions with those in the 250-station, national air-sampling network operated by the Public Health Service. It may also define a mill's contribution to local situations.

Council's staff has integrated the most desirable meteorological and ambient air sampling techniques for routine ambient air surveys into bulletin form. This is in the process of being updated at the present time.

6. Cooperative mill service activities

Service activities in air pollution by the regional engineers cover a wide spectrum and are increasing. Typical of these are those listed below:

(1) Collection, compilation, and dissemination of information.
(2) Design of ambient air surveys.
(3) Training of mill personnel in sampling and analytical techniques.
(4) Conference with members on control measures as well as data interpretation.

7. Staff technical activities

Previous factors of the report have described those programs and activities which have as their main purpose generation of new knowledge in the fields of emission measurement and control technology, and pollution effects of our atmospheric emissions. There are several additional technical areas calling for increased activity on the part of our staff. These involve (a) the continuing inventory of new emission control measures, their costs, effectiveness, and application; and (b) the continuing review of existing and proposed control-regulations as an aid to member mills involved in cooperative efforts to develop equitable control codes at the state and local levels.

(a) Continuing Review of Emission Control Measures

Traditionally, the National Council has played an important role as a clearing house of stream-improvement technical information, combining compilations of current practice with technical analysis to identify important process parameters, and to indicate which practices are worthy of extension. To an increasing degree, we are being called on to play this same role in the air pollution areas as more mills adopt control measures or begin active evaluations of alternative control systems. In this respect, mention should be made of a number of such studies performed in the areas of black liquor oxidation, electrostatic precipitation ratings, lime-kiln, venturi-scrubber performance, total sulfur emission, and the impact of particulate emissions on ambient air quality as measured by fallout rates and suspended particulate levels. We are now completing an industry-wide enumeration of control practices employed at kraft mills and are preparing reviews of heavy black liquor oxidation practice and secondary scrubbing of recovery furnace stack gases. Some preview data is presented in *Figure 3*.

FIGURE 3.—*Air pollution control activities of kraft pulp mills*

Ambient air survey program	32
High efficiency recovery furnace stack devices	27
High efficiency scrubbing of lime kiln stack	38
Black liquor oxidation	27
Smelt tank demisting	21
Noncondensible oxidation	22
High-efficiency fuel burning stack devices	5

(*b*) *Continuing Review of Control Agency Regulations*

We have been continually active since 1956 in providing information on proposed air pollution control legislation, particularly that involving the setting of standards of emission or of ambient air quality. Such legislation has prompted increased activity on the Council's part in evaluating existing and proposed regulations. In such states as Pennsylvania and South Carolina this has recently taken the form of:

(1) Determining what levels and forms of emission control will be required to achieve compliance with proposed regulations. These frequently include limitations on sulfur concentration in exit gases as well as total emission weight per unit of material processed. This inventory information is of great value in answering questions.

(2) Indicating under what conditions certain forms of regulation are more pertinent than others (i.e., limits on emission vs. changes in ambient air quality).

(3) Indicating the extent and type of monitoring efforts that will be required to demonstrate compliance with various regulations.

We expect to see a steady growth in the Council's effort in these two directions which provide both a balance to our total program and a necessary link between our own investigative efforts and the mills' continuing progress in air pollution control.

C—IDENTIFICATION OF RESEARCH UNITS

1. Odor evaluation and non-sulfur odor sources

The most significant need is in the area of evaluation of source and control. While the sulfur compounds have been given credit for the typical kraft odor, little has been done in attempting to chemically characterize other compounds present in small concentrations, which are contributing factors, by the use of chromatographic isolation and infra-red spectophotometry. Chemical characterization of odor may have merit over subjective testing by humans, whose response is variable. It is, however, becoming obvious that at least some subjective testing in connection with chemical characterization may be desirable and a necessary adjunct to study programs where various control techniques are being evaluated.

2. Role of direct contact evaporation and black liquor oxidation in odor emission and control

Considerable emphasis has been placed on the role of the contact evaporator as a source of H_2S emission. With present black liquor oxidation practices this component can be substantially reduced or virtually eliminated at this source. This has reduced but not eliminated the odor problem, and at least three facets of black liquor oxidation are deserving of further attention. These include the following:

(1) Refined chemical characterization of gaseous effluent components present with and without black liquor oxidation.

(2) Relationship of degree of black liquor oxidation and sulfur emission or odor emission.

(3) Relationship of high-degree black liquor oxidation, odor threshold, and refined chemical characterization.

The first of these is under study at the present time. It has been demonstrated that the rate of H_2S evolution is inversely proportional to the degree of black liquor oxidation. There is no information to indicate whether organic sulfur or other odorous compound evolution follows a similar pattern. Since the organic sulfurs may constitute the bulk of the sulfur loss at this source, this aspect is deserving of attention.

There is considerable speculation concerning the merits of indirect evaporation in controlling odor emission. The issue is by no means resolved and at least one major manufacturer is piloting a unique air-to-air heat exchanger for this purpose. Without exception the merits of indirect evaporation are based on the premise that odor emission from a furnace is, or can be, relatively non-existent. This, to our knowledge, has not been demonstrated by subjective odor tests nor have sulfur losses from the furnace *per se* been adequately documented using the more refined analytical techniques now available, such as chromatography. The actual role of the recovery furnace in sulfur and odor emissions under normal load should be established in order that indirect evaporation can be properly evaluated as a pollution control device.

3. Absorption and oxidation of odor compounds

Beyond the conversion of some sulfur compounds to more stable forms or major process changes, such as elimination of contact evaporation, the ultimate control of odor rests almost entirely on oxidation of malodorous compound to ones of lower threshold or preferably having no unpleasant odor. A multitude of odor sources exist which may ultimately require treatment. These include those listed below:

(1) Recovery furnace stacks of kraft and semi-chemical pulp mills.
(2) Digester relief and blow gas.
(3) Evaporator non-condensables.
(4) Black liquor oxidation tower off-gas.
(5) Condensate scrubbing off-gas.
(6) Washer room vents.
(7) Lime kiln stack.

This is a wide array of point-source emissions, varying both in intensity and volume. All, however, are presently under scrutiny to varying degrees by regulatory agencies, and five mills are now required to report loads from two or more of these sources on a routine basis.

(*a*) *Chemical Absorption and Oxidation*

The present status of knowledge and work in progress in the area of chemical oxidation on absorption with particular reference to chlorine and caustic was described earlier in the report. Their limited effectiveness suggests the need for further evaluation of other oxidants such as iron, ozone, and permanganate—as well as oxidation catalysts such as oxides of nitrogen.

The need for development of a highly effective oxidant is increasing as the older decentralized kraft mills initiate pollution abatement at widely dispersed points. This need is not, however, confined to older mills, since it is impossible to devise a highly refined control scheme, short of thermal oxidation in the furnace or auxiliary equipment, which does not encompass chemical oxidation.

(*b*) *Thermal Oxidation*

Thermal oxidation in theory is the most positive means of reducing the threshold odor level of sulfur compounds as well as many other organics to a minimum. Cursory laboratory observations and sulfur measurements on lime kiln exhausts where non-condensables are being burned confirm this theory. Its use as an ordor control measure on recovery stack gas may seem premature. Its effectiveness cannot be overlooked, however, and subjects such as minimum temperature requirements for oxidation of odorous compounds as well as compilation and evaluation of heat recovery schemes should be a portion of the research program.

4. Summarized Odor Research Needs

Three areas of study have been set forth as probably being the most productive in getting at solutions to the odor problem. These include: (1) definition of full capability and limitations of black liquor oxidation; (2) evaluation of the effects of major process changes, such as elimination of the stack evaporator; and (3) evaluation of chemical and thermal oxidants. While these cover a wide spectrum, all are of major significance.

5. Particulate Emission

Data tend to point to the fact that in most cases adequate means are available at present for gross particulate matter control from power boilers, as well as the bulk of the recovery operations. There exist localized situations where questions are arising concerning the role of particulate matter as nuclei in fog formation.

The most significant lack of knowledge in particulate removal lies in the means to reduce discharge from stacks behind venturi recovery units to a level commensurate with that obtainable where precipitators are employed.

The question of relationship of particulate matter fallout and corrosion, particularly paint damage, arises on occasion. No controlled experimental data are available relating such factors as amount of salt cake, humidity, and time of exposure on corrosion rate of metal surfaces or paint. Constructive work could therefore be done in this area.

6. Control of SO_2 Emissions

Finally, the increased attention being given to sulfur dioxide emissions and the sulfur content of fossil fuels suggests that we analyze our position in this matter. We are conscious of the implications, and future developments may require more emphasis on researching means of controlling sulfur dioxide.

Attachment No. 4

International Research Conference on Atmospheric Emissions From Sulfate Pulping

The following papers will serve to introduce the various subjects for discussion at the Conference. As seen from the attached schedule, approximately three of these papers of no more than twenty-five minutes' duration each will be presented each session followed by discussion.

MONDAY A.M.

"The Importance of the Kraft Pulping Industry," David Knowlton, Knowlton Brothers, Inc., Watertown, N.Y.

"Development of Governmental Programs of Improved Air Quality", Vernon G. MacKenzie, Public Health Service, Washington, D.C.

"Basic Theory and Practice of Pulping", Virgil Minch, Mead Corporation, Chillicothe, Ohio.

"Chemistry and Physics of Pollutant Formation", Irwin Douglass, University of Maine, Orono, Maine.

"Effects of Emissions", R. L. Stockman, Wash. Dept. of Health, Seattle, Wash., and Donald Anderson, University of British Columbia, Vancouver, British Columbia.

MONDAY P.M.

"Methods of Evaluation—Physico-chemical", Donald Adams, Washington State Univ., Pullman, Wash.

"Methods of Evaluation—Organoleptic", Lars Friberg, Swedish Institute of Hygiene, Stockholm, Sweden.

"Methods of Evaluation–Socio-economic", Austin Heller, Public Health Service, Cincinnati, Ohio.

TUESDAY A.M.

"Abatement Procedures Presently in Use or Feasible", "Digesters and Their Operation", George De Haas, Weyerhaeuser Company, Tacoma, Wash.

"Black Liquor Oxidation", Frank Murray, British Columbia Research Council, Vancouver, British Columbia.

"Evaporators and Their Operation", David Wetherhorn, Continental Can Company, Savannah, Ga.

TUESDAY P.M.

"Recovery Furnaces and Their Operation," Norman Westerberg, Ekono, Helsinki, Finland.

"Lime Kilns and Their Operation," Edward Taylor, Georgia-Pacific Corp., Toledo, Oreg.

"Other Operational Sources," Waldo Chastant, International Paper Co., Mobile, Ala.

WEDNESDAY A.M.

"Variations in Pulping Practices which May Affect Emissions," William Major, West Virginia Pulp & Paper Co., Covington, Va.

"Adaptation of Successful Control Techniques from One Mill to Another," Isaiah Gellman, National Council for Stream Improvement, Baltimore, Md.

WEDNESDAY P.M.

"Role of Management in Air Pollution Abatement," Fred Adams, Owens-Illinois, Inc., Toledo, Ohio.

"Effect of New Process Technology on Air Pollution Potential," Kyosti Sarkanen, University of Washington, Seattle, Wash.

THURSDAY A.M.

"Summary and Identification of Research Needs," Summary Committee.

ATTACHMENT No. 5

IDENTIFICATION OF RESEARCH NEEDS IN PREPARED PAPERS AND RELATED DISCUSSIONS

A. Identification of Air Pollution Effects:
1. Improve methodology for physico-chemical effects.
a. Material damage—paint, corrosion;
b. Changes in visibility.
2. Improved methodology for epidemiological studies.
a. Selection of suitable control communities, population groups, and observation intervals.
b. Selection of appropriate air quality parameter for correlation with epidemiological data and other human responses.
3. Improved methodology for determining losses in socio-economic values resulting from A–P.

B. New and Improved Analytical Techniques:
1. Methods for trace organic compound detection in ambient air.
2. Methods suited to detection of production processes malfunction.
3. Methods suited to control of abatement processes (i.e. reliable H_2S meter).
4. Organoleptic techniques for odor threshold determination on process emission, and evaluation of ambient air (quantitative and degree of acceptability).

C. Recovery Furnace Odor Emission Prevention and Control:
1. Chemical characterization of non-sulfur compounds in recovery furnace emissions.
2. Evaluation of indirect evaporation as odor control measure—comparison with BLO followed by direct contact evaporation.
3. Basic studies of wet scrubbing designed to remove odor compounds (oxidants other than chlorine, alkaline solutions).
4. Continuing design studies concerned with multifunction nature of furnace.

D. Black Liquor Oxidation—Identification of catalytic agents, effect of pH and thiosulfate concentration on reaction rate and completion; effect on subsequent evaporation emissions (compounds other than hydrogen sulfide); effect of tonnage oxygen use on reactions of reduced sulfur compounds other than hydrogen sulfide.

E. Improved treatment methods for sources such as evaporator and smelt dissolving tank gases (alternative scrubbing systems).

F. Comparison of Odor Emission from lime recovery using rotary kiln vs fluidized bed calciner.

G. Continuing Studies of Pulping Processes:
1. Comparison of emissions from batch and continuous digesters.
2. Development of processes yielding pulps comparable to kraft and providing reduced odor emission or simplified emission control.

H. Specialized meteorological studies—transformations of kraft emissions during travel from source to ground level.

Senator MUSKIE. Our last witness of the day is Dr. Allen D. Brandt, manager of industrial health engineering, Bethlehem Steel Corp.

STATEMENT OF ALLEN D. BRANDT, MANAGER, INDUSTRIAL HEALTH ENGINEERING DIVISION, INDUSTRIAL AND PUBLIC RELATIONS DEPARTMENT, BETHLEHEM STEEL CORP.

Mr. BRANDT. Senator Muskie, members of the Subcommittee on Air and Water Pollution, I am Allen D. Brandt, manager of industrial health engineering, Industrial and Public Relations Department, Bethlehem Steel Corp.

I am chairman of the Pennsylvania Air Pollution Commission; I have served as chairman of three different councils of technical advisers appointed by the New York State Air Pollution Control Board to develop three specific documents involved in the State's air pollution control regulations; and I am a member of the American Iron & Steel Institute's Technical Committee on Air and Water Quality Control.

I have been active in the field of air pollution control for almost 30 years. During that time, it has been my privilege to serve a 4-year term from 1954 to 1958 on the U.S. Public Health Service Research Grants Study Section which dealt with air pollution and to serve for three successive terms as chairman of the Environmental Engineering Intersociety Board, Inc., a professional engineering organization which grants certificates of competence to qualified licensed engineers engaged in one or more aspects of environmental engineering, including air pollution control.

It is interesting to note also that as long ago as 1942 at which time I was a regular corps commissioned officer in the U.S. Public Health Service, I was the chief of a team which investigated an interstate air pollution problem between Tennessee and Virginia at Bristol caused by a secondary lead smelter.

You have asked me to discuss the efforts of the steel industry to develop methods for air pollution control. While I appear before you today on behalf of Bethlehem Steel Corp., this statement has been endorsed by a large segment of the steel industry. I am grateful for the privilege of presenting this statement on the status of air pollution control and technology in the steel industry.

Before discussing the state-of-the-art of air pollution control and what the steel industry is doing to find solutions to those problems for which adequate control measures are not known, I would like to give merited recognition and praise to the committee, especially to you Senator Muskie and the members of your subcommittee, for the sincere and understanding way in which the complex and difficult matter of air and water pollution control legislation has been handled. The spirit of cooperation and the understanding of the problem exhibited by the committee are commendable, indeed. In addition, I want to commend the Research Management Advisory Panel of the Subcommittee on Science, Research, and Development to the Committee on Science and Astronautics, U.S. House of Representatives, for the fine report it prepared last year entitled "The Adequacy of Technology for Pollution Abatement." The members of that committee merit congratulations for their depth of understanding of the pollution abatement field manifested in their very complete, yet succinct, report.

By all odds, the most important air pollutant discharged by the steel industry is particulate matter. Admittedly, there are several other pollutants which deserve mention; they will be referred to briefly near the end of this statement.

STATE-OF-THE-ART WITH ATTENDING LIMITATIONS

While there remain several important particulate matter air pollution sources in the steel industry as to which practicable solutions are not known, I am glad to report that substantial progress has been made by the steel industry during the past 15 years in finding solutions to most of the major sources of pollutants and in applying proven air pollution control equipment to many of those sources. Not all of that progress has been achieved through the installation of air pollution control equipment. Many process and equipment changes have been effected in the industry with the result that (1) the amounts of pollutants produced by certain specific sources have been reduced substantially, (2) sources which previously had been difficult to control have been so modified as to permit effective control with today's technology, and (3) some sources have been eliminated completely.

In general, today's technology permits the control to a reasonably high degree of particulate pollutants (dusts and fumes) from (1) blast furnaces, (2) sinter plants, (3) steelmaking furnaces, with the exception of electric furnaces, and (4) coke plant operations with the exception of charging and emptying the ovens. To achieve adequate control, however, each system must be carefully designed and tailor-made to best accommodate the source in the space available if the full capabilities of the collector proper are to be realized. This is especially true in ironmaking and steelmaking furnaces. Most blast furnaces are provided with good control, usually consisting of two- or three-stage collection equipment which prevents nearly all of the dust from being discharged to the outside air. All basic oxygen furnaces in the United States are provided with equally effective, though usually single-stage, collectors for the dust and fume produced. Similarly, most oxygen-lanced open-hearth-type steelmaking furnaces are provided with high efficiency equipment, or are programed to be so equipped. In addition, some conventional open hearth furnaces are provided with effective pollution control. However, inasmuch as the conventional open hearth steelmaking furnaces are being replaced rapidly by basic oxygen furnaces and electric furnaces, it is unlikely that air pollution control equipment will be installed at many of the remaining operating furnaces because of the cost involved.

While sinter plants as originally constructed were not provided with air pollution control equipment at all sources needing control, and the efficiency of the collectors installed where control equipment has been provided is inadequate, all sinter plant sources of importance are being brought under control as time, equipment, and funds permit. Similarly, the dust-producing operations in coke plants, with the exception of charging and emptying (pushing) the ovens, are being brought under control. At the moment practicable means for controlling the coke fines released during quenching are not known. However, in light of today's technology, there is little doubt that an acceptable solution will be found before long.

(More detailed information on the status of control may be found in the paper "Current Status and Future Prospects—Steel Industry Air Pollution Control" which I presented at the National Conference on Air Pollution in Washington last December.)

To restate the situation very briefly, the current technology is adequate for control of particulate matter air pollutants in the steel industry at most of the major sources, specifically blast furnaces, basic oxygen furnaces, open hearth furnaces, both conventional and oxygen-lanced, sinter plants, and coke plants, except for charging and pushing the ovens.

Most of the foregoing major sources are under control, and the steel industry is engaged in a program of applying the best equipment currently available to the remaining uncontrolled sources, and of upgrading all existing control systems which do not meet today's high standards, as time, equipment, and funds become available.

PARTICULATE POLLUTANT SOURCES WHERE AVAILABLE CONTROL TECHNOLOGY IS INADEQUATE

Electric furnaces used for making conventional steel can be provided with pollution control equipment which is effective during the melting and refining cycle. Many furnaces are so provided.

However, it is impracticable with today's technology to prevent the escape of dust into the furnace building during charging. Control of the fume generated during melting and refining is achieved by means of an exhaust system connected to the roof of the furnace.

During top charging, however, the roof must be swung aside with the result that the control becomes ineffective, and the dust created by charging escapes into the building.

In addition, in the case of electric furnaces making specialty steels (alloy and tool steel), it is impracticable to control the fumes during that part of the refining cycle when reducing slag operations are carried out.

Consequently, satisfactory control of dust and fume produced by electric steelmaking furnaces is not practicable with today's technology.

Charging coke ovens and emptying them, which is done by pushing the red hot coke out one end of the oven from the opposite end, results in the release of air pollutants for which there is no known way today to either prevent their escape or capture them effectively. While noteworthy improvements and equipment changes have been developed in recent years, the best control that can be accomplished today leaves much to be desired. What is more, for the older ones—and most of the ovens in this country are in that class—some of the control techniques developed recently cannot be applied for one reason or another.

For many years, technical representatives of the steel industry of the United States have been visiting foreign countries and vice versa to observe and exchange information regarding steel industry practices, including air and water pollution control procedures and techniques, in other countries. In recent years special attention has been paid to coke-making plants by many of the representatives in the hope of finding solutions to the problems attending coke oven operations, especially the charging and pushing operations. Based on information

77-515 O—67—pt. 4——11

currently available, it appears that improvements can be made in the charging equipment to reduce the amount of pollutants escaping from the charging operations. However, as indicated earlier, such modified charging equipment may not be usable on many of the older ovens currently operating in the United States. With respect to the air pollutants released during coke pushing, development work has not yet progressed to the point where a good opinion can be formed as to the likelihood that it will provide worthwhile control. However, the steel industry is engaged in a diligent and intensive study of the air pollution problem at coke ovens and it is hoped that improvements applicable to all ovens in the country will be developed.

Another troublesome problem, though spasmodic in occurrence, is that resulting from the fine dust picked up by the wind from the steel industry's stockpiles of basic raw materials; namely, coal, ore, and limestone. A practicable solution to this problem is not available, nor does one appear on the horizon.

GASEOUS POLLUTANTS

The major gaseous pollution is sulfur dioxide. Inasmuch as sulfur is an unwanted ingredient in steel processing and a highly undesirable element in most steel products, the steel industry is singularly careful to use coal and oil which are low in sulfur content. For that reason, the steel industry discharges much less sulfur dioxide than does any other industry using the same amounts of coal and oil. As a result, the sulfur dioxide problem has not appeared to be of major concern in most of the communities where steel plants are located, though the ambient air quality standard for SO_2 recommended recently by the Public Health Service is causing more than a little concern in the industry.

It is well known that practical means are not available today for the removal of sulfur from coal or sulfur dioxide from stack gases. This situation is acknowledged and discussed in the report "The Adequacy of Technology for Pollution Abatement" prepared by the Subcommittee on Science, Research, and Development of the Committee on Science and Astronautics, U.S. House of Representatives, 89th Congress, second session, and in a recent report issued by the U.S. Public Health Service titled "Technological Change as it Relates to Air Pollution" under the heading "Major Unsolved Technical Problems."

The sulfur in hot blast furnace slag forms hydrogen sulfide upon wetting. Therefore, if a slag disposal area is located in the vicinity of homes or other occupied buildings, an objectionable odor problem may be created during periods of fog or rain, especially under calm conditions. A solution to this problem is not known at present though both the American Iron and Steel Institute and the National Slag Association are sponsoring research aimed at finding a satisfactory solution. This is an area in which much more research is necessary.

Help on these remaining unsolved problems is welcome from any and all sources.

STEEL INDUSTRY RESEARCH

Research and development efforts are being carried out by individual steel companies and by groups of companies who have a common problem. In addition, the industry supports research which is spon-

sored by and through the American Iron and Steel Institute. Even though the remainder of the discussion on this specific subject will emphasize only the American Iron and Steel Institute sponsored research, many steel companies individually and/or collectively deserve credit for the research being conducted into new and improved methods of air pollution control. While much of this research is of an applied nature, some of it is quite fundamental. It might be well to add in this connection that there is a remarkably free interchange of information pertaining to pollution control matters among the different steel companies with the result that the findings by any company with respect to a new method or an improved procedure become common knowledge in the industry in a very short period of time.

Without trying to be all-inclusive, I believe mention should be made not only of current, but also of some of the past, research sponsored by the American Iron and Steel Institute. In terms of instrumentation for air pollutants, two automatic ambient air sampling devices, the AISI dust sampler and the AISI H_2S sampler were developed almost 15 years ago. More recently, a monitoring device for the particulate matter in the stack effluents from metallurgical furnaces was developed by a research team at Harvard and the first prototype has been tested on an open hearth and on a basic oxygen steelmaking furnace. It is under test at present at a blast furnace. Also, a remote sensing direct reading absorption spectrometer for the detection of sulfur dioxide and certain other gases including nitrogen oxides is under development for AISI by Barringer Research, Inc. The AISI has not obtained patents on any of these devices. Rather, papers describing the instruments have been presented at technical society meetings as soon as feasible after the instruments were developed in an attempt to make such information available to all concerned.

In the area of fume control, a research project was conducted by the late Dr. Silverman at Harvard beginning in 1953 and continuing for about 10 years in an attempt to find improved and less costly gas cleaning equipment for metallurgical furnace stacks.[1] Several pilot plants were developed which were tested at steel plants. In the final analysis, the equipment so developed did not appear to have significant advantages over commercially available high efficiency collectors such as electrostatic precipitators, high energy wet collectors, and fabric filtration (baghouses). In 1958, Battelle Memorial Institute was asked to study the mechanism by which fumes are formed in metallurgical operations and to evaluate possible methods for reducing the amount formed. While the laboratory findings indicated that additions of methane, hydrogen, and steam to the oxygen achieved considerable fume suppression, trials at an open hearth steelmaking furnace demonstrated that the additives were not sufficiently effective to justify their use.

Recognizing that high temperature operations create nitrogen oxides, a project was initiated at Harvard University recently for the purpose of determining whether such gases are created in sufficient quantities by steelmaking operations to be of concern from the air pollution viewpoint. So far as we know, nitrogen oxides do not con-

---

[1] See p. 2390 for a partial list of papers published.

stitute a steel industry problem at present. However, in view of the constantly increasing concentration of automobiles in many areas, we are interested in evaluating as well as is possible today what is in prospect for the future in this regard.

An investigation on animals of the possible health effects of typical steel community particulate pollutants in meaningful concentrations in the presence of sulfur dioxide, also in meaningful concentrations, is in progress at the Harvard School of Public Health.

In an effort to find a means of controlling the air pollutants escaping when coke ovens are emptied, a subcommittee of the American Iron and Steel Institute Air and Water Quality Control Committee is drafting a contract to let with a still-to-be-chosen qualified engineering consulting firm. The objective of that project is to bring outside engineering talent into the picture for a concentrated drive to find a practicable approach to the control problem.

With respect to the hydrogen sulfide problem at blast furnace slag disposal piles, Battelle Memorial Institute has been engaged for the past 2 or 3 years on a study of the mechanism of formation of hydrogen sulfide from blast furnace slags. If the exact reaction mechanism involved can be identified, the chances of finding feasible means of suppressing the formation of that gas may be improved. At the same time, the National Slag Association has a committee which is coordinating work being done principally by steel company research laboratories in an effort to find a solution to the problem, possibly by means of appropriate additives or other treatment of the slag in the molten state.

COST OF EQUIPMENT

The equipment required for controlling air pollution in the steel industry varies tremendously from source to source, and from place to place, depending on the availability of space, and other factors. Consequently, it is difficult to categorize the cost of such facilities in a meaningful manner. A recent survey by the AISI shows that the industry spent $239 million for air pollution control from 1951 to 1965. The current spending rate is much higher, of course.

CONCLUSIONS

Technology today is available for the control of most of the particulate air pollution problems created by the steel industry. Many of the sources which were not controlled as recently as 10 to 15 years ago have been brought under excellent control, and currently the steel industry is engaged in a program of installing appropriate equipment at all major sources as to which pollution control solutions are known. Because of the fantastic costs involved, and because of the other problems associated therewith, such as availability of space, availability of equipment, and time required for the construction of such equipment, the control phase in which the industry currently is engaged will not be completed overnight. I am convinced that more good can be done by the Federal Government in bringing about air pollution control at those sources for which practicable answers are available by appropriate financial incentives to the affected industries than by making a comparable amount of money available in grants

to others to try to develop less expensive equipment or methods, neither of which currently appears on the horizon. In this regard, I would like to quote briefly from the report "The Adequacy of Technology for Pollution Abatement" which was referred to earlier in this statement.

What the Nation needs is not the revenue from penalty fines imposed on polluters; rather, the need is for reduction in the volume of pollutants discharged to the environment. The rapid amortization of pollution abatement equipment would be a spur toward achieving widespread and timely installation of such equipment.

The use of indirect incentives to increase industrial participation in pollution research will place the resulting technical knowledge directly where it is to be applied. Lags in application due to information or technology transfer problems may be reduced.

The pressures for pollution abatement are strong and the responsibility of industry is generally accepted. However, the pace at which improvement is achieved remains an important variable. The cost and financing of abatement equipment should not seriously disrupt the capital investment for expansion and modernization. The tax incentive seems to be a way to balance these investment requirements.

The steel industry today is engaged in an energetic drive to find answers to the problems mentioned earlier herein for which solutions are not known at present. It will continue that search unstintingly. At the same time, Federal assistance in the form of tax credit is not only welcome, but solicited. The need for such assistance was recognized last year by the members of the committee who drafted the report "The Adequacy of Technology for Pollution Abatement."

I am grateful for the privilege of presenting this statement and trust the information contained in it will be helpful to the committee in its deliberations.

I thank you, sir.

Senator MUSKIE. Thank you, Mr. Brandt.

On page 9 of your statement, you referred to several projects that were developed in the area of fume control. Could you supply for the record a list of these plants and the basic approaches and costs associated with each?

Mr. BRANDT. You are talking about the second paragraph?

Senator MUSKIE. Yes.

Mr. BRANDT. Yes; I believe we can provide that information, sir.

Senator MUSKIE. You spoke of a paper that you gave here in Washington.

Mr. BRANDT. That is correct.

Senator MUSKIE. If that is sufficiently different from this and in sufficiently greater detail, we would be delighted to have it for the record.

Mr. BRANDT. Thank you. It is of considerably greater detail, Senator Muskie.

Senator MUSKIE. We would like to have it then.

(Subsequently Mr. Brandt submitted the following letter and enclosures:)

BETHLEHEM STEEL CORP.,
Bethlehem, Pa., May 22, 1967.

Hon. EDMUND S. MUSKIE,
Chairman, Subcommittee on Air and Water Pollution, Committee on Public Works, U.S. Senate, Washington, D.C.

DEAR SENATOR MUSKIE: During the discussion following the statement which I presented before your Subcommittee on Air and Water Pollution in Washington

on Monday, May 15, you asked for certain information with respect to expenditures made by the steel industry in research and development in the control of air pollution. At that time I was not certain whether such information is available, but I agreed to try to obtain it.

It appears, unfortunately, that meaningful or accurate information on the subject cannot be extracted from the records of the steel industry.

In response to your question with respect to the several projects referred to on page 9 of my statement, the money paid to Harvard for their research project on fume control at metallurgical furnaces was more than $400,000. That figure includes only the money paid to Harvard, not to the costs to the steel plant at which the crude pilot plants were installed and tested. The project at Harvard had as its objective the development of a less costly and more practical method of removing the fumes from the stack gases at metallurgical furnaces.

With respect to the project at Battelle which also was conducted over a period of about 8 years, the amount paid to Battelle was more than $300,000. The Battelle project was aimed at suppressing or preventing the creation of fumes in the furnace proper.

Enclosed herewith is a list of references to some of the articles which have been published as a result of the Harvard and Battelle studies. References 1 through 6 pertain to the Harvard project and references 7 and 8 pertain to the Battelle study.

In response to your other requests, a copy of the paper "Current Status and Future Prospects—Steel Industry Air Pollution Control" given at the National Conference on Air Pollution in Washington last December and a copy of Pennsylvania's ambient air quality criteria are enclosed.

Sincerely yours,

A. D. BRANDT,
Manager of Industrial Health Engineering.

REFERENCES TO SOME OF THE PAPERS PUBLISHED AS A RESULT OF RESEARCH PROJECTS AT HARVARD AND BATTELLE

1. Pilot-Plant Studies of a Continuous Slag-Wool Filter for Open Hearth Fume by Charles E. Billings, W. David Small and Leslie Silverman. Journal of the Air Pollution Control Association, Vol. 5, No. 3, Nov., 1955.

2. Research and Development of Equipment for Cleaning of High Temperature Gases by Leslie Silverman. Transactions of 21st Annual Meeting of Industrial Hygiene Foundation, Pittsburgh, Pennsylvania, November 14–15, 1956.

3. Further Investigations of the Continuous Slag-Wool Filter by C. E. Billings, L. H. Levenbaum, C. Kurker, Jr., E. C. Hickey and L. Silverman. Journal of the Air Pollution Control Association, May, 1958.

4. Simultaneous Removal of Acid Gases, Mists and Fumes with Mineral Wool Filters by Charles E. Billings, Charles Kurker, Jr. and Leslie Silverman. Journal of the Air Pollution Control Association, Vol. 8, No. 3, Nov., 1958.

5. Shock Wave Cleaning of Air Filters by Charles E. Billings, Leslie Silverman, Richard Dennis and Lester H. Levenbaum. Journal of the Air Pollution Control Association, Vol. 10, No. 4, August, 1960.

6. High Temperature Filter Media Performance with Shock Wave Cleaning by Charles E. Billings and Leslie Silverman. International Journal Air and Water Pollution. Pergamon Press, Vol. 6, pages 455–466, 1962.

7. Formation and Suppression of Emissions from Steelmaking Processes by George W. P. Rengstorff. The Metallurgical Society of the American Institute of Mining, Metallurgical, and Petroleum Engineers. Proceedings of the 44th Conference, National Open Hearth Steel Committee of the Iron and Steel Division, Vol. 44, April 10–12, 1961.

8. Role of Methane and Other Factors in Controlling Emissions from Steelmaking Processes by George W. P. Rengstorff. The Metallurgical Society of the American Institute of Mining, Metallurgical, and Petroleum Engineers. Proceedings of the 46th National Open Hearth and Basic Oxygen Steel Conference of the Iron and Steel Division, Vol. 46, April 1–3, 1963.

CURRENT STATUS AND FUTURE PROSPECTS—STEEL INDUSTRY AIR POLLUTION CONTROL PRESENTED AT NATIONAL CONFERENCE ON AIR POLLUTION DECEMBER 13, 1966, WASHINGTON, D.C.

While it is well-know that steel-making and processing require tremendous quantities of air, the exact amount per ton of steel products made is not known.

There is little doubt, however, that the amount used exceeds the amount of steel made many times, even on a weight basis. Much of the air "used", of course, is not changed significantly in quality as a result of its use. On the other hand, many of the operations involved in steel-making and processing impair the quality of the air used to some degree. Therefore, air treatment or air pollution control equipment is now, and for many years has been, used extensively in the steel industry. The rate at which such equipment is being installed is accelerating rapidly in an effort to keep pace with the increased need as a result of the rapidly increasing rate at which air pollutants are being discharged into the air by an ever increasing number and complexity of sources.

AIR POLLUTANT SOURCES IN THE STEEL INDUSTRY

The major sources of air pollutants in the steel industry may be divided into five groups:

(1) Coke Ovens.
(2) Blast Furnaces (including Sinter Plants).
(3) Steel-making Furnaces.
(4) Boiler Houses.
(5) Miscellaneous.

STATUS TODAY AND FUTURE PROSPECTS

Coke Plants.—The major air pollution problem created by coke-making plants is that of settleable particulates (coal and coke dust). The sources of coal dust and coke dust in a coke-making plant are many and varied. Since most of them are the fugitive type (rather than captive), many of the important ones are difficult, if not impracticable, to prevent or control.

In addition to the coke and coal dust problems associated with coke-plant operations, sulfur dioxide, and on occasion, hydrogen sulfide and other gaseous products from the destructive distillation of coal escape from the coke-making operations in sufficient quantity to evoke complaints from nearby residents who are located downwind from the plant.

Sulfur is an unwanted ingredient in steel processing and a highly undesirable element in steel products. Therefore, the steel industry is meticulous about the sulfur content of the raw materials entering the steel-making operations, including the fuel consumed in the steel refining processes. As a result, the coal used in coke-making is extraordinarily low in sulfur content, averaging very close to 1%. Consequently, even though the amount of coal consumed by the industry in making coke is very large, the amount of SO_2 created and emitted into the air is relatively low and has not been a serious problem in the past except in isolated and sporadic instances.

The escape of hydrogen sulfide and of gaseous products from the destructive distillation of coal in quantities of sufficient magnitude to create problems, or to evoke complaints from nearby residents, generally occurs only infrequently. Small amounts of such pollutants escape almost continuously from some of the many possible emission points at coke ovens. However, it usually is only the unexpected and abnormal event which permits the escape of a sufficient amount of such pollutants to create a temporary pollution problem.

Today, more than at any time in the past, the steel industry is engaged in a concerted program of top-flight operation and maintenance of its coke ovens in an effort to hold to the irreducible minimum the amount of smoke and gases escaping from the ovens. It is impossible with current coke-making equipment and procedures—that is to say, with current coke-making technology—to make coke without permitting some of the pollutants to escape. Fortunately, with carefully operated and well-maintained ovens the quantities escaping usually are so small as not to generate valid objections on the part of nearby residents. Coke-making is the major remaining operation in the steel-making industry where complete and satisfactory control of the air pollution problem is sorely dependent on a breakthrough in technology. While there is promise that the research currently in progress will bring about reductions of some of the sources such as those associated with the charging operations, there is little hope of a complete solution to the coke-making problem short of a major change in technology.

Blast Furnaces.—It has been standard practice in the steel industry for many years to clean to a high degree most of the heavily dust-laden blast furnace gases produced in steel-making. Approximately 3.5 tons of blast furnace gas are gen-

rated for each ton of pig iron produced. Until recently the amount of dust captured per ton of pig iron produced was in the neighborhood of 200 pounds. Consequently, the magnitude and cost of the equipment needed for blast furnace gas cleaning has been tremendous.

Even though the art of blast furnace gas cleaning has been well-known for many years and has been practiced rather effectively, one aspect of blast furnace operation has been responsible until recently for considerable air pollution. The problem, which resulted from blast furnace "slips", arose whenever the burden, or contents, in the furnace bridged over and failed to settle uniformly. When the bridge collapsed the entire burden settled rapidly and unevenly, permitting a tremendous volume of heavily dust-laden air to pass up through the furnace and to escape to the outside through automatic valves so as to prevent a dangerous build-up of pressure in the blast furnace gas piping system. These "slips", as they are called in the industry, resulted in the release of huge clouds of very dirty, completely untreated blast furnace gas.

The tremendous improvements made 10 to 15 years ago in blast furnace feed materials and in instrumentation have reduced almost to the vanishing point the number of slips occurring in blast furnaces. In addition, a change in the piping system and in the permissible top pressure has made it possible to contain most slips which actually do occur. The result is that it is very rare today for a slip of such magnitude to occur as to spring the escape valves high on the furnace and allow the heavily dust-laden gases to escape to the outside.

While the number of slips occurring in a large steel plant 15 years ago might have exceeded even 100 in a bad day, it is very rare today to experience any slips which are vented to the outside. What is more, the gas cleaning facilities currently available at most blast furnaces employed in steel-making are such as to reduce the dust burden in the gases to a concentration of 0.01 gr/scf or less.

Consequently, the tremendous dust problem which is inherent in the making of pig iron is under good control today. What is more, as further improvements are made in blast furnace feed materials and in instrumentation, the occasions on which blast furnace slips occur and are vented to the outside will become even rarer than they are today. In other words, the potentially huge air pollution problem posed by blast furnaces in the steel industry is being controlled very effectively.

Sintering Plants.—Most large steel plants include a sintering plant. It provides a means of converting fine ore as well as many of the metallic waste products, such as blast furnace dust, machine shop turnings, mill scale, etc. to a porous clinker-type mass which is suitable for blast furnace feed.

The sinter plant has several important sources of dust, the major ones being the windbox gases and the sinter belt discharge. While most, if not all, sinter plants have collectors for removing the dust from the windbox gases, some of them are not of a type or of a capacity to permit cleaning the air to the levels required today. Many of the collectors were installed years ago and were in keeping with the standards then existing. Most sinter belt discharges were not provided with dust collectors until early in the past decade.

The sinter plant does not pose a problem which is incapable of solution. It seems reasonable, therefore, to expect that most sinter plants will be provided with adequate dust control equipment in the future as time, money and equipment become available.

Steel-Making Furnaces.—For many years the bulk of steel was made in open hearth furnaces; between 80 and 90 per cent of the steel produced in the industry was made in open hearth furnaces until a few years ago. The other types of furnaces in common use today are electric furnaces and basic oxygen furnaces. These types of steel-making operations will be discussed in turn.

1. *Open Hearth Furnaces.*—Prior to about 1955 all open hearth steel was made in conventional furnaces. The process was a slow one requiring 9 to 12 hours per heat. The development of the oxygen-lancing procedure about 1955 made it possible to so accelerate the steel refining process as to permit the making of a heat in about 6 hours. However, the use of oxygen-lancing increased tremendously the fume production with the result that a serious air pollution problem was created by the furnaces which were oxygen-lanced. The fume production rate which averaged around 12 lbs. per ton of steel in uncontrolled open hearth furnaces was increased substantially in oxygen-lanced furnaces. Because of the tremendous variation from furnace to furnace and the dependence on the oxygen feed rate, a good average for the amount of fume per ton of steel produced by the oxygen-lancing process has not been reported. Presumably it ranged between 15 and 25 lbs/ton.

Because of the great increase in fume production when using the oxygen-lancing process, most such furnaces were provided with adequate air pollution control equipment as rapidly as installation of the necessary equipment could be made. There are some exceptions, to be sure, but in the main, the open hearth furnaces converted to oxygen-lancing are equipped with good control.

Because of the relatively low rate of fume produced by the conventional open hearth process, and because of the uncertainty as to the need for pollution control on such furnaces, relatively few conventional open hearth furnaces have been provided with pollution control equipment. Those factors together with the replacement of conventional furnaces by other processes make it unlikely that many conventional open hearth furnaces will be provided with pollution control equipment in the future.

2. *Basic Oxygen Furnaces.*—The basic oxygen furnace, or the basic oxygen process as it is more properly called, is a European development which was first used in the United States in 1955. During that year only about 300,000 tons out of total steel production of 117 million tons was made by the basic oxygen process. However, because of its superiority over the other methods of refining steel, the basic oxygen process has been adopted rapidly and by the end of this year will be accounting for production at an annual rate of about 38 million tons out of a total production rate for the year of about 134 million tons. In other words, in a period of twelve years, the basic oxygen furnace production rate in the United States has risen from zero to about 28 per cent of the total steel production rate and it will continue to rise rapidly in the future.

Because of the advantages of the basic oxygen process, the most important being the very short cycle time of about 45 minutes, the conventional open hearth is being replaced rapidly by basic oxygen furnaces. Therefore, it is only a matter of time until all except a rather small proportion of the steel currently made in conventional, and uncontrolled open hearth furnaces, will be made in basic oxygen furnaces. The advent of the basic oxygen process has been most fortunate for the steel industry. The age, space requirements and nature of operation of the conventional open hearth furnace are such as to make it impracticable in most instances to apply well-designed and effective air pollution control equipment.

Basic oxygen furnaces produce copious amounts of fume, which, while it varies tremendously from operation to operation, probably is around 25 lbs/ton. But since all such furnaces have been constructed during the past 10 or 11 years, the era during which air pollution control reached maturity, every furnace built in the U.S. has been provided with good air pollution control equipment as an integral part of construction. There is little doubt that this procedure will be followed meticulously in the future with the result that as the conventional open hearth production capacity is replaced by basic oxygen furnace capacity, the air pollution control problem which existed in the past and continues even today from steel-making operations will be resolved.

Since the steel-making furnaces as recently as a few years ago constituted by all odds the major air pollution source in the industry, the impact of the basic oxygen furnace on the air pollution control program in the industry is apparent.

3. *Electric Furnaces.*—The third method of refining steel is the electric furnace. It is peculiarly well-adapted to steel-making in plants which do not have blast furnaces, and where hot metal is therefore, not available. The time required to make a heat in the electric furnace is about 4 hours.

The amount of steel made in electric furnaces increased over the 25 year period (1941 through 1965) from 2.9 to 13.8 million tons annually. In terms of per cent of total production rate, the increase was from 3.5 to 10.5 per cent.

Because of an inherent characteristic of the construction and operation of steel-making electric furnaces, they create a unique air pollution control problem which is very difficult to solve. Such furnaces are charged by swinging the roof aside. Owing to the overhead equipment and structure required for the normal operation of the furnaces, it is impossible to design an effective hooding or "capture" system for the clouds of air pollutants which emerge from the furnace when a charge of cold scrap metal is dropped into it. While it is quite common to provide a system of control by means of a direct or indirect roof take-off which achieves effective dust and fume control during the melting and even during the tapping operation, a technologically acceptable method has not yet been found to my knowledge for capturing the pollutants and heavily-polluted air escaping during the charging operation.

In support of the foregoing statement, I can speak first-hand and with feeling. At Bethlehem's electric furnace melt shop in California a total elapsed period of about 15 years was required to resolve to the satisfaction of the regulatory agency the problem of pollutant escape from the furnaces, principally that escaping when charging. The story of that pollution control installation should give pause to any and all who think, and continue to repeat, that proven solutions are known to all air pollution control problems. At the very least such statements should be qualified with respect to the time period that sometimes is required to achieve an acceptable solution.

In brief, air pollution control at electric furnaces can be achieved without difficulty for the refining and tapping periods, but not for the charging operations. It is my considered opinion that the charging problem will not be resolved to the satisfaction of all concerned until and unless electric furnaces or the materials charged into them are so altered as to permit doing so without the removal of the roof, as, for example, through an enclosed screw-feed system. It is eminently important that such a system be developed promptly, for as the older cold charge open hearth furnaces in isolated areas require complete rebuilding, the economics well may favor replacement by more versatile electric furnaces.

Boiler Houses: One other significant source of air pollution in integrated steel-making plants is the coal-fired boiler. Most such boilers operated by the steel industry today are provided with some degree of control. The control equipment in many instances is that which was considered adequate at the time the installation was made. Others have excellent control, and as time goes on improved pollution control facilities are being added where required as time and funds permit.

Miscellaneous Sources: Most steel plants operate maintenance foundries. There is nothing unique about air pollution control problems attending such foundries, and the degree of control provided is about the same as is found in the foundry industry generally. However, as is the case for the steel industry generally, the control facilities are being replaced or upgraded as is necessary to reamin abreast of the pertinent air pollution control laws and regulations.

The storage piles of ore, limestone and coal create problems in periods of high winds and dry weather which are difficult of solution. A satisfactory answer to the problem does not appear on the horizon at the moment. Since the particulate matter involved usually is large in size and much of it is heavy, it creates mainly a problem of dustfall for a relatively short distance downwind from the pile. Therefore, the plants in which such piles are located more or less centrally may be fortunate enough to avoid all except an occasional and rare problem. By the same token, the plants which by dint of circumstances have the storage piles of raw materials close to property lines probably are creating air pollution problems in the areas immediately downwind therefrom. This is an area in which great need for research exists. Effective and not prohibitively costly methods of treating such piles to prevent the dust from becoming air-borne during high winds, especially in prolonged cold weather, are sorely needed.

SULFUR DIOXIDE

Relatively little was said earlier about sulfur dioxide. There are several reasons for this apparent oversight.

In the first place, because sulfur is an unwanted ingredient in the steel-making processes and an undesirable element in steel products, the steel industry is very meticulous as to the sulfur content of the coal used in making coke and in the fuel consumed in the steel-making furnaces. As a result a steel plant emits much less sulfur dioxide than would another industrial plant using the same amount of coal and oil.

Secondly, there is sharp divergence of opinions among the authorities in the air pollution field as to the importance of sulfur dioxide in the concentrations normally found in the ambient air, even in large cities where the day to day concentrations are relatively high, to say nothing about the many smaller communities where the sulfur dioxide levels are much lower. In other words, there is lack of agreement as to what the ambient air quality criteria or standards should be for sulfur dioxide.

Lastly, it is recognized by most responsible and knowledgeable people in the air pollution field that a practicable means is not available today for the removal of sulfur dioxide from stack gases. This situation is acknowledged and

discussed in the report "The Adequacy of Technology for Pollution Abatement" prepared by the Subcommittee on Science, Research, and Development of the Committee on Science and Astronautics, U.S. House of Representatives, 89th Congress, Second Session, and in a recent report issued by the U.S. Public Health Service titled "Technological Change as it Relates to Air Pollution" under the heading "Major Unsolved Technical Problems".

FUTURE PROSPECTS—GENERAL

During the past year or two the steel industry has made it abundantly clear that an aggressive program of air pollution control will be carried out in its many and varied plants. The many statements which different steel company executives have made during the past year indicate that it is following a four-point policy which is:

1. All new plants and equipment which release sufficient air pollutants to be of concern will be provided during construction with pollution control facilities which are adequate to meet the pertinent laws and regulations, if such facilities are available.
2. The air pollution control facilities at existing plants and equipment will be improved as needed where feasible, or will be replaced with new and adequate air pollution control facilities where such are available, as rapidly as time, money, manpower and equipment permit so as to meet the existing laws and regulations.
3. With respect to those sources for which practicable solutions are not known, research and investigations will be carried forward aggressively with a view toward developing air pollution control equipment which is capable of meeting the pertinent laws and regulations.
4. The steel industry will cooperate with all levels of government in developing comprehensive pollution control programs and in intensifying the research activities in those areas where practicable solutions are not currently known.

The air pollution control activities of the steel industry in recent years give substance to the recent pronouncements by high-level steel industry executives with respect to the plans of the industry for air pollution control. Recent newspaper accounts are replete with references to the large amounts of money being spent and/or committed for air pollution control equipment in different areas of the country. What is more, during the past 15 years the steel industry has spent an estimated $250 million on air pollution control equipment—equipment which currently is costing the industry an estimated $30 million annually to operate. Such equipment does not, of course, produce marketable products, and therefore income. It is for that reason that the industry continues to stress the importance of appropriate tax incentives to help ease the financial burden being incurred.

While it is impossible, of course, for the industry to make accurate estimates of the amounts of money to be spent in the future for air pollution control equipment, it is likely that the annual rate of expenditure during the next 5–10 years will exceed that during the past 15 years. There is reason to believe that with the assistance being provided by technological improvements in prospect for all areas of steel industry operations, the anticipated expenditure rate for air pollution control facilities during the next 10–15 years will have resulted in adequate control of all sources of particulate pollutants with the exception of relatively few minor and scattered sources.

SUMMARY

Rather than attempt to summarize what has been presented in the paper, a few cardinal points will be emphasized.

1. Air pollution control at blast furnace operations, in general, is excellent.
2. The most important single contributor of particulate air pollutants in the steel industry today, namely, the steel-making furnaces, is being brought under control rapidly and effectively as a result of the change in steel-making technology whereby uncontrolled conventional open hearth furnaces are being replaced by Basic Oxygen Furnaces equipped during construction with adequate air pollution control facilities.
3. The nature of the equipment and procedure currently employed in making coke for the steel industry does not permit complete control of the air pollutants created by such operations. A technological breakthrough is essential to the attainment of adequate and satisfactory air pollution control at coke-making operations.

4. Technological improvements are needed to permit effective and practicable control of the sporadic air pollution created when high winds blow across stock piles of coal, ore and stone.

5. The steel industry has made noteworthy progress in air pollution control in recent years and presently is engaged in a program of control which will make steel plants relatively free from major particulate air pollution problems by the end of the next decade.

COMMONWEALTH OF PENNSYLVANIA, DEPARTMENT OF HEALTH, AIR POLLUTION COMMISSION, AMBIENT AIR QUALITY CRITERIA

Adopted: April 25, 1967.

I. INTRODUCTION

In accordance with Section 5(f)(8) of the Pennsylvania Air Pollution Control Act, the Act of January 8, 1960, P.L. 2119, on April 25, 1967 the Air Pollution Commission adopted the Ambient Air Quality Criteria shown below.

On this same date, the Commission appointed a Council of Technical Advisors on Ambient Air Quality Criteria as a continuing body to periodically review the adopted criteria and report to the Commission, at least once a year, on suggested modifications or additions, if any, to these criteria and/or to the reference standard sampling and analytical procedures.

II. PURPOSES

The following criteria will be used by the Commission in:

1. Evaluating the results of community air pollution studies conducted by the Department of Health.

2. Determining the need for air pollution control regulations in regions of the Commonwealth to achieve these objectives.

3. Developing rules and regulations in accordance with Section 5(f)(2) of the Pennsylvania Air Pollution Control Act.

III. CRITERIA

Until additional pertinent information becomes available with respect to the effects of the substances listed below which leads to recommendations by the Council and to revision or addition by the Commission, the following air quality criteria shall apply in Pennsylvania:

Ambient air quality criteria, 1967*

A. AIR BASIN AVERAGE (†)

Substance	30-day	24-hr.	1-hr.
1. Suspended particulates (total)	100 μg./M³		
2. Settled particulates (total)	1.0 mg./cm.²		

B. SINGLE POINT MEASUREMENT

1. Suspended particulates (total)	150 μg./M³	500 μg./M³	
2. Settled particulates (total)	1.5 mg./cm.²(‡)		
3. Lead (tentative)	5 μg./M³		
4. Beryllium	0.01 μg./M³	(§)	
5. Sulfates (as H_2SO_4)	10 μg./M³	30 μg./M³	
6. Sulfuric acid mist		(§)	(§)
7. Fluorides (total soluble, as HF)		5μg./M³	
8. Sulfur dioxide	0.05 p.p.m	0.25 p.p.m	0.5 p.p.m.
9. Nitrogen dioxide	(§)		
10. Oxidants		(§)	(§)
11. Hydrogen sulfide		0.005 p.p.m	0.1 p.p.m.
12. Carbon monoxide		25 p.p.m	

*Maximum values, not to be exceeded.
†Based upon results from geographically uniformly spaced sampling stations.
‡Not to be exceeded as the average of 3 successive sampling periods.
§The Council of Technical Advisers on Ambient Air Quality Criteria is directed to consider such criterion.

The values listed above should be considered as representing minimum quality, not necessarily desirable quality. They should be considered as goals, not necessarily immediately obtainable. The values are not precise and some deviation from the values is not evidence of injury or adverse effects. In general, the criteria are based on a dosage concept and require both the presence of a receptor and an exposure time equal to or greater than those listed.

Blank spaces in the listing are purposeful. In general, for the range of concentrations encountered in outdoor air, substances with 30-day values only have chronic effects; substances with 24-hr or 1-hr values only have acute effects; substances with all three time interval values have both chronic and acute effects. Effects considered are both biological and physical.

The Commission will publish and make available a supplement to these criteria containing information on which the criteria are based. This supplement will be revised from time to time as the criteria are revised or as additional information becomes available.

IV. SAMPLING AND ANALYTICAL PROCEDURES

The sampling and analytical procedures employed to measure ambient levels of contaminants are to be consistent with obtaining accurate results which are representative of the conditions being evaluated. The following sampling and analytical techniques may be used directly or employed as reference standards against which other methods may be calibrated. These listed techniques are subject to revision, as provided for in Section I.

Reference standards, 1967

Substance	Sampling method	Analytical method
Suspended particulates (total)	High-volume filtration (1)	Gravimetric (1).
Settled particulates (total)	Open top cylinder (2)	Gravimetric (2).
Lead	High-volume filtration (1)	Spectrographic (1).
Beryllium	do	Do.
Sulfates	do	Turbidimetric (3).
Fluorides	Filtratiion plus gas absorption (4)	Zirconium eriochrome cyanine (4).
Sulfur dioxide	Gas absorption (5), (6)	Pate, et al modification of West-Gaeke method (5), (6).
Nitrogen dioxide	Gas absorption (7)	Griess-Saltzman method (7).
Hydrogen sulfide	Gas absorption (8)	Methylene blue method (8).
Carbon monoxide	Long path cell (9)	Infrared absorption (9).

NOTE.—Numbers in parentheses refer to references listed at end of document.

V. REFERENCES

(1) "Air Pollution Measurements of the National Air Sampling Network: Analyses of Suspended Particulates 1957–1961," Public Health Service Pub. No. 978, Washington, D.C., 1962.

(2) "Recommended Standard Method for Continuing Dust Fall Survey (APM–1, Revision 1)," TR–2 Air Pollution Measurements Committee, *J. Air Poll. Control Assoc.*, 16:372 (1966).

(3) Interbranch Chemical Advisory Committee, "Selected Methods for the Measurement of Air Pollutants," PHS Pub. No. 999–AP–11, Cincinnati, Ohio, 1965, p. I–1.

(4) "Standard Method of Test for Inorganic Fluoride in the Atmosphere," ASTM Standards on Methods of Atmospheric Sampling and Analyses, Philadelphia, Penna., 1962, p. 67.

(5) West, P. W. and Gaeke, G. C., "Fixation of Sulfur Dioxide as Disulfitomercurate (II), Subsequent Colorimetric Estimation," *Anal. Chem.* 28:1916 (1956).

(6) Pate, J. B. et al., "Nitrite Interference in Spectrophotometric Determination of Atmospheric Sulfur Dioxide," *Anal. Chem.*, 37 :942 (1965).

(7) Saltzman, B. E., Colorimetric Microdetermination of Nitrogen Dioxide in the Atmosphere," *Anal. Chem.*, 26:1949 (1954).

(8) Jacobs, M. B. et al., "Ultramicrodetermination of Sulfides in Air," *Anal. Chem.*, 29:1349 (1957).

(9) Jacobs, M. B., et al., "Continuous Determination of Carbon Monoxide and Hydrocarbons in Air by a Modified Infrared Analyzer," *J. Air Poll. Control Assoc.*, 9:110 (1959).

Senator MUSKIE. Do you have any data on the expenditures of the industry in the research and development field?

Mr. BRANDT. I do not have it and I am not quite sure such information could be developed, Senator Muskie, and supplied. I do not have it at hand.

Senator MUSKIE. Well, if it could be done, we would appreciate it.

Mr. BRANDT. Thank you.

Senator MUSKIE. I take it that although particulate control is the large problem of the steel industry, it is also the area in which you have achieved the greatest progress?

Mr. BRANDT. This is correct.

Senator MUSKIE. You have indentified the different areas.

What percentage of particulate problem of the industry do you think is now subject to available technology and so is subject to control?

Mr. BRANDT. If you are thinking of it as of this minute rather than as of 10 years ago, it would vary tremendously from place to place because at some plants much more progress has been made than at other plants. Consequently, it is conceivable that doing all that we say can be done in this paper at a given plant might not reduce the particulate more than 10 percent whereas at another it might be 90 percent depending on what has already been done.

Senator MUSKIE. That is a difference that relates to the time that the plant was built?

Mr. BRANDT. No, sir. That is a difference that relates basically to how much money is available to pay for equipment because the equipment is being installed pretty much on a priority basis. Enough money is not available to apply solutions to all problems at one time; consequently, they are being done on the basis of where they are needed most.

This is determined on the basis of the ambient air quality in the area and what are the applicable regulations. In other words, is the plant in the center of a large urban community or is it out in a small community where it does not create near the problem because there are not as many other sources adding to the load in the area.

Senator MUSKIE. Is it the view of the industry that as new plants are constructed available technology to control air pollution should be built into it?

Mr. BRANDT. Yes, sir.

Senator MUSKIE. Whatever the location of a plant?

Mr. BRANDT. Yes, sir.

Senator MUSKIE. So that, whether a new plant is located in an area which now has an air pollution problem or not, the new plant would be equipped with the latest available air pollution control equipment?

Mr. BRANDT. I believe that is correct, sir.

Senator MUSKIE. Now, the industry has been, has it not, involved in a major updating of plant and equipment in recent years in the development of new steelmaking processes?

Mr. BRANDT. That is true, but that applies largely as you imply to the steelmaking processes; yes.

Senator MUSKIE. As contrasted to——

Mr. BRANDT. Cokemaking by way of example.

Senator MUSKIE. What aspect of the steel industry now causes the greatest air pollution control problem?

Mr. BRANDT. The metallurgical operations, the steelmaking operations do. Nevertheless, there are some citizens who are located close to a coke plant rather than a steel plant and to them it is the coke plant.

In terms of pollutants, mass emission rates, it is the steelmaking furnaces rather than the coke furnaces that discharge most to the air.

Senator MUSKIE. What problems would the national emission standards apply to the steel industry? What problems do such standards create for the industry technologically?

Mr. BRANDT. Well, I don't think you can separate technology from economics in that regard, Senator Muskie. If national emission rates were established for the steel industry, they would have to be set on some basis, presumably on the basis of what may be required in a large urban metropolitan area, which means they would be quite severe.

This in turn means that in other communities, especially in the case of a small community where the only significant or really important source is that of the steel plant, you would have to go much further than is necessary to get good ambient air.

Consequently, economically, money would be wasted; you are spending money at one place while it would be better if you would put that money at a place where it is needed much more. So, it is economically unsound and scientifically unsound to have national emission limitations. I am not talking about ambient air quality criteria; I am talking about emission limitations.

Senator MUSKIE. A moment ago, you said it was the policy of the industry when it built a new plant to install the latest available air pollution control equipment wherever the plant is located.

Now, would you feel, therefore, that it would be consistent with this policy to require that new plants meet national emission standards?

Mr. BRANDT. Again, I don't think it is sound to require national emission standards because whether or not you spend, for example, a stated amount or twice that much depends on what the problem is in the community in terms of ambient air quality.

Senator MUSKIE. If you are now building into new plants all that is possible with present-day technology, the national emission standards could not require more than that.

Mr. BRANDT. We do not build in all that is possible unless that is necessary.

Senator MUSKIE. I see. That is the clarification I would like you to make. Generally, how do you determine what available technology you build into new plants and what technology you do not build into new plants?

Mr. BRANDT. It is based largely on two factors: One, the cost involved because as you go, for example, from 90 percent collecting efficiency in a precipitator collector, for example, to 99 percent collecting efficiency, you double the collector cost. If you go to 99.9 percent you roughly double the cost again. Consequently, based on the ambient air quality in the area and what limits you are trying to achieve or not exceed, you would decide whether you are going 90, 95, 99 or 99.9 percent because the cost is a great deal more as you go higher.

Therefore, you can achieve 90 percent at a relatively low cost and

if that is adequate to prevent the creation of a problem, you would build something better than 90 percent.

Senator MUSKIE. The testimony this morning was that there are very few States, and I don't think they were able to identify more than two this morning, where ambient air quality criteria are now established or identified. If that is the case, then those criteria certainly are not available to you in most parts of the country to help you decide how much air pollution control technology you are building in your new plants.

Mr. BRANDT. They overlooked Pennsylvania. Not that that is too important, Senator, but I happen to come from Pennsylvania and I am chairman of the air pollution commission. At the last meeting we did adopt ambient air quality criteria for the State. The important thing is that the industry before it proceeds has an awfully good feeling for what is acceptable quality and what is not. In other words, what levels should you attain?

Therefore, knowing what exists in the area where you are going to build a new plant or where you are now putting in some control facilities on an existing plant, you can determine fairly well, fairly accurately, how far you need to go at least to reach the ambient air quality criteria or not exceed it, as the case may be.

Senator MUSKIE. That is sort of flying by the seat of your pants, isn't it?

Mr. BRANDT. I don't think so. I think this is a matter of using ambient air quality criteria scientifically and of solving each problem on an individual basis.

Senator MUSKIE. Let me ask you this: Are steel mills, by and large, located in what are called by the Census Bureau standard statistical metropolitan areas? I am not sure I got those words in the right order. That is a rather cumbersome description but, nevertheless, I think that is close enough.

Are steel mills pretty much located in areas of that kind or a significant portion of them located in a nonmetropolitan area?

Mr. BRANDT. I don't know the definition that separates one from the other but most of them——

Senator MUSKIE. Well, one figure that would give you a rough clue is the population of 50,000.

Mr. BRANDT. Most of them are in urban areas by that definition; in or adjoining.

Senator MUSKIE. Now, relatively few of these, only 16, according to the Public Health Service testimony this morning, I could be wrong, have continuous air monitoring networks. In the absence of such networks, is it possible to establish air quality criteria?

Mr. BRANDT. I don't think that ambient air quality criteria should be based solely on those network stations; the criteria we are talking about.

Senator MUSKIE. Who decides what the criteria should be?

Mr. BRANDT. The Public Health Service recommended one recently, but long before that the U.S. Public Health Service published recommended—I am not sure that "recommended" was the term used, but they proposed ambient air quality criteria which they believed we should try to achieve. Those go back at least 4 or 5 years, I believe, and

have served as guides in places where there has not been any other information.

In the case of Pennsylvania, we could, of course, be guided by the ones that were under consideration for a long time by the health department for adoption by the Air Pollution Commission.

Senator MUSKIE. Are you speaking of ambient air quality criteria for particular cities or are you speaking of acceptable emission criteria for that particular pollutant?

Mr. BRANDT. I am talking about air quality criteria which serve as guides for deciding how far to go.

Senator MUSKIE. There are 212 of these metropolitan areas which the Census Bureau identifies as areas of 50,000 or more. Now, each of these is different from all of the others, I suspect, in terms of concentrations of industry, the kinds of industry, other sources of pollution and resultant air quality.

It seems to me that if a steel plant going into any one of these areas is undertaking to determine in advance how much air technology is available, it ought to know specifically with respect to the city involved what the quality of air is, what the existing pollutants are, how much they can be added to, and what the resultant quality would be after the new plant is in operation.

Now, is this the kind of process that you get into when you decide how much control equipment to build into your steel plant?

Mr. BRANDT. That is some of the information. As a rule, at least some of the industries, and I can speak only for Bethlehem Steel Corp., but some others have done some air monitoring in the area where they are going to put the facilities.

So, you have some firsthand data of the quality, in addition to the information provided by the Public Health Service air sampling network, not only as to that city but others which they classify by size of city. You can then apply all available information in deciding whether to spend $5 million, $2 million, or $1 million for air pollution control at that plant.

Senator MUSKIE. This is a process that the industry is involved in. Does it consult with local health authorities or State health authorities in making this determination?

After all, the future growth of a city depends not only upon the corporate decision of a single company but upon the decisions of other companies in the area, the objective population goal, and so on in developing its future shape with respect to air pollution.

Now, how does an industry doing its own monitoring reach a decision that it is going to prove to be livable and viable in the context of all of the other decisions that will be made affecting the air quality of that city in some reasonable future?

Mr. BRANDT. The steel industry has built, of course, only very few new plants or is starting to build very few plants in new locations. At those places considerable is known with respect to the air quality in the community or in the surrounding areas either from the Public Health Service, national air sampling network data, or through the information that the plant management itself has developed. It is by putting all this information to use and looking at it in total that gives the industry a guide as to where it should go.

77-515 O—67—pt. 4——12

Senator MUSKIE. Is there a Public Health Service sampling facility available in each of the cities in which a new steel plant has been built in the last 10 years?

Mr. BRANDT. I don't believe any new steelmaking plants have been built in the last 10 years.

Senator MUSKIE. Any modifications of the existing plants?

Mr. BRANDT. The U.S. Public Health Service network has had stations in many of them. I would not want to say in all, but many of the locations where steel plants are located; yes.

Senator MUSKIE. Now, the Public Health Service has told us that every city of 12,000 or more has air pollution problems by virtue of the American automobile population.

You say that most of your steel plants are in such areas.

It would seem to me, therefore, that as you build new plants or replace old ones your policy ought to be building in every bit of technology that is available at any given time, if you are really going to gear the future operations of that plant to the future of the area.

Mr. BRANDT. In the main, the problem in many areas is created by the automobile. In other words, the Public Health Service in stating that there are problems in practically every community of 50,000 or more, means one problem or another, not a combination of one and another and another. In one it might be largely sulfur dioxide; in another it might be particulate matter, and in another some specific pollutant instead of all of them together.

As indicated in my prepared statement, the main problem the steel industry faces is particulate pollutants. If you are in an area where the particulate load is not high, there is no need for concern by the steel industry regarding, for example, hydrocarbons, the oxidants, and other pollutants which may be a problem there. We don't contribute to them in significant amounts.

Senator MUSKIE. I think in almost every city of 50,000 you are going to have a particular problem whether the steel mill is located there or not, from open dump burning of municipal solid wastes, to fuel consumption in residences and other industries, to leaf-burning in the fall, and many other sources. When you reach the population of 50,000, considering future population growth and the growth of industry, it would seem that you ought to begin eliminating sources, from whatever sources, as fast as the technology makes possible.

The national population will probably double in the next 33 years. Considering this it seems to me that any new plant that goes into a city, which has technology to prevent smoke, ought to install that equipment, whether or not at that particular moment there is air pollution with serious impact upon the health of human beings or biological impact on plant and animal life.

I just don't see how industry ought to make the assumption that it can do less than what is available to it in controlling smoke under these circumstances.

Now, that may seem like a radical point of view, but I don't think so. When we look back to the extent upon which the air pollution control problem has grown since World War II, we have to assume that when you are talking about a city of this kind we better begin controlling what is controllable just as far as we can, lest the problem get unmanageable.

Senator SPONG. May I interrupt here and be sure I understand Mr. Brandt?

Senator MUSKIE. Yes, sir.

Senator SPONG. In response to a question whether an industry in a particular location would try for the maximum of control, you said that there were two determining factors.

You said the first factor was cost and that the cost of control would double as a plant moved from 90 to 97 percent control and perhaps double again in attaining complete control of pollution.

I have gathered that the second factor would be the pollution condition in a particular location.

Mr. BRANDT. That is correct, sir.

Getting back to Senator Muskie's question, I think it is more important here that we install adequate equipment than that we install the very last bit of control that can be achieved.

For example, take an existing steel plant, to begin with, which is now operating a number of steel furnaces, whatever they may be, and which at the moment may have no control or might have partial control. By putting on 99 percent control, 98 or anything better than 95, as a matter of fact, you reduce tremendously the total amount of emission. To go from 95 up to 99 percent almost doubles the collector cost. Hence if that extra money were applied to control another source about 95 percent, you would be eliminating a much larger segment of the total existing pollution. You would be discharging much less particulate matter by applying the controls to two sources than by looking for the maximum of 99.9 percent more, and would do much more good, with the money available, since the funds are not unlimited.

Senator MUSKIE. Well, I am afraid that the example you pose is one I cannot grasp although it is probably a perfectly valid illustration of your point. I cannot grasp it because it would strike me offhand that the difference between 95 and 98 would not be worth fighting over anyway.

But, if it is worth fighting over to the point where that additional technology has been developed, then it would seem to me it ought to be used. In other words, it is hard for me to conceive, I am sure, because I am not familiar with the technology in the industry, that the difference between 95 and 98 can mean that much in terms of additional costs unless it means a great deal more than is evident in the percentages in terms of results.

Mr. BRANDT. Well, it does for certain types of equipment, as, for example, the precipitator which, as you know, is a very common type of device in use, because the efficiency of it is a function of a number of things but especially of the retention time in the unit, itself. Consequently, to double the retention time, and thereby reduce the velocity going through by a factor of 2, you must pay for two units.

Senator MUSKIE. What you are saying is that that 3 percent in performance can be very meaningful in some environments and meaningless in others.

Now, is that actually the case?

Mr. BRANDT. Yes; that is actually the case because in some places where the existing air quality is relatively bad, it would be well to apply a much higher degree of cleaning—by much higher, I am talking about the difference between 95 and 98 or 99-plus percent collecting efficiency.

This is not common as a rule in places of 50,000 or even relatively larger urban areas. It might be important in some of the very large ones like New York, Philadelphia, Chicago, possibly Los Angeles.

Senator MUSKIE. Now, if that 3- to 4-percent addition can be meaningful today in one given metropolitan environment, it represents apparently a lot of dust. If it does, can it also be meaningful in a city of 50,000?

Mr. BRANDT. Probably not, but, generally speaking, the regulations that are in existence in the United States, as, for example, the Los Angeles one which was about the first one adopted, employed the process weight basis for limiting the discharge. By that rule you are allowed to discharge an increasing amount of particulate matter as defined by a curve up to a maximum of 40 pounds per hour; no more than that no matter what the nature of the process. Regulations of that kind have caused the expenditure of needlessly large amounts of money in certain areas to get 99-plus efficiency where it isn't necessary.

In other words, some regulations go needlessly far by permitting so very little to be discharged. This is not the best way to solve the air pollution problem in this country in terms of particulate matter.

Senator MUSKIE. Well, I guess perhaps we have sharpened the point as well as we can with my limited knowledge of the industry, unless Senator Spong could sharpen it a little more.

Senator SPONG. I would like to ask Mr. Brandt to comment further on your statement when you say:

> For that reason, the steel industry discharges much less sulfur dioxide than does any other industry using the same amounts of coal and oil. As a result, the sulfur dioxide problem has not appeared to be of major concern in most of the communities where steel plants are located, though the ambient air quality standard for SO_2 recommended recently by the Public Health Service is causing more than a little concern in the industry.

Mr. BRANDT. Which part of that?

Senator SPONG. All that I read.

Mr. BRANDT. The steel industry uses coal and oil which is unusually low in sulfur because of the impact that sulfur in the process has on the final product. As a result, the amount of sulfur dioxide discharged for the large amount of oil and coal used is much less than it would be for another industry using a like amount of customary coal and oil.

Based on past thinking with respect to sulfur dioxide in the concentrations existing in many cities and communities where the steel industry has plants, we did not feel that it created a problem. We still feel it does not, though the Public Health Service recommended limit of 0.015 part per million is giving some concern to the industry. That is considerably lower, as I am sure you realize, than was proposed in the past.

We were thinking until recently in terms of past standards, and for that matter still are, because we question whether the low value that is recommended by the Public Health Service is indeeded necessary.

Senator MUSKIE. I see.

Senator SPONG. I see.

Senator MUSKIE. Is your concern partly directed toward the question of whether or not there would be sufficient quantity of low-sulfur-content fuel to serve both your needs and other needs in cities subject to such control?

Mr. BRANDT. No; it is for the reason that in those communities in which steel plants are located and where the sulfur dioxide content in the air now may exceed 0.15 p.p.m., in the past we did not think constituted a problem. We still think it does not constitute a problem.

Senator MUSKIE. Senator Tydings.

Senator TYDINGS. Yes.

You are a Marylander, Mr. Brandt?

Mr. BRANDT. No, sir; I am not. I am from Pennsylvania.

Senator TYDINGS. Have you ever been to Sparrows Point?

Mr. BRANDT. Yes, sir.

Senator TYDINGS. Well, I don't see how you can say that the sulfur dioxide problem does not appear to be a major concern in most communities where steel plants are located. It is a frightful problem in Baltimore.

Mr. BRANDT. That could be, in Baltimore. For the Sparrows Point plant, however, the amount of sulfur discharged is extremely small.

Senator TYDINGS. What do you mean?

Mr. BRANDT. For a steel plant of that size, and because of the control that has been built into the plant for sulfur dioxide, the amount being discharged is very small.

Senator TYDINGS. You said it does not appear to be a major concern. Now, it may be small for the size of the plant but it certainly is a major concern.

Mr. BRANDT. But I don't believe that the problem in Baltimore County comes from Sparrows Point. In fact, sulfur dioxide comes——

Senator TYDINGS. It is one of the contributing factors.

Mr. BRANDT. If so, it is a small one.

Senator TYDINGS. Well, would you like your family to live in Sparrows Point next to the steel mill?

Mr. BRANDT. If I were to say no, it would be because of the particulate matter, not because of this sulfur dioxide.

Senator MUSKIE. No more questions of Mr. Brandt?

Senator SPONG. No.

Senator MUSKIE. Thank you, Mr. Brandt. I am sorry we could not get to you this morning.

Mr. BRANDT. Thank you.

Senator MUSKIE. We have very little time left this afternoon.

We will adjourn then and will recess until 9:30 tomorrow morning.

(Whereupon, at 3:05 p.m., the subcommittee recessed, to reconvene at 9:30 a.m., Tuesday, May 16, 1967.)

AIR POLLUTION—1967

TUESDAY, MAY 16, 1967

U.S. SENATE,
SUBCOMMITTEE ON AIR AND WATER POLLUTION
OF THE COMMITTEE ON PUBLIC WORKS,
Washington, D.C.

The subcommittee met, pursuant to recess, at 9:35 a.m., in room 4200, Senate Office Building, Senator Edmund S. Muskie (chairman of the subcommittee) presiding.

Present: Senators Muskie, Randolph, Spong, Boggs, Cooper, and Baker.

Also present: Richard B. Royce, staff director; Leon G. Billings, professional staff member; Richard D. Grundy, staff member; and Richard E. Gerrish, minority staff director.

Senator MUSKIE. The subcommittee will be in order.

I regret that I have to leave to preside over other hearings in about 45 minutes, but I would like to begin these hearings at least.

Our first witness this morning, on the subject of sulfur research and development, is Mr. James R. Garvey, president and director of research of Bituminous Coal Research, Inc.

Mr. Garvey, it is a pleasure to welcome you this morning.

STATEMENT OF JAMES R. GARVEY, PRESIDENT AND DIRECTOR OF RESEARCH, BITUMINOUS COAL RESEARCH, INC.

Mr. GARVEY. Thank you, Senator.

Mr. Chairman and gentlemen of the committee, my name is James R. Garvey. I am president and director of research of Bituminous Coal Research, Inc., with offices and laboratory at Monroeville, Pa. BCR is an affiliate of the National Coal Association, and through this affiliation serves as the research agency for the bituminous coal industry.

I am also vice president, research and engineering, of National Coal Association, and work closely with its air pollution control division in Washington, which also maintains eight engineers in the field working on combustion and air pollution problems. I might add that Joseph W. Mullan, who is manager of NCA's air pollution control activities, is also vice president of the Air Pollution Control Association and has been named general conference chairman of the Second International Air Pollution Conference to be held in Washington in 1970. Agencies of the Federal, State, and local governments, as well as numerous industries make constant use of the technical services available through our air pollution control division.

On May 9, it was emphasized that NCA has been active in air pollution control for over 25 years. BCR, likewise, was very active in research, including sulfur removal, long before there was any public concern over the possibility of health hazards.

Just 2 years ago, I had the pleasure of appearing before this committee and testifying regarding the "state of the art" of sulfur oxide control.

I am happy that I have been invited back to talk again on the same subject, and my only regret is that I cannot say that we have found the magic answer to this problem.

But, I can tell you that substantial progress has been made during the past 2 years, and I hope that as a result of the presentations made here today, not only by me, but by others who will appear, you will conclude that we are moving toward a practical solution.

I hope you will also conclude, as I have, that finding a solution through technology development must precede the imposition of the unrealistic limits on sulfur oxide emissions and/or sulfur content of fuels being suggested by some public health officials.

Senator MUSKIE. May I ask a question?

Mr. GARVEY. Yes.

Senator MUSKIE. I am going to interrupt because I have to leave and I want to ask the questions that trouble me when they occur to me, if I may.

Now, the public officials who testified here insisted that they do not intend to ask for controls that are not justified by the state of the art and reasonable economics.

Now, that suggests to me that your criticism is relevant only if you object to the substitution of lower sulfur content fuels to meet the limits that are suggested, so I wish you would clarify that point. In other words, if we are going to rely upon technology wholly as a way of improving the situation relative to the sulfur content of the ambient air, we have the assurances of the administration witnesses here that they will not ask for what cannot be achieved by available technology. It is clear that they think we can achieve some improvement by the substitution of fuels.

Now, do you consider that a legitimate approach at all? If so, in what circumstances, and, if not, why not?

Mr. GARVEY. Where the low sulfur fuels are available and where there are no other means for control of ambient air quality; that is, if this is the only approach that is available, it is a logical way to do it.

However, it is our contention, our belief, that the availability of low sulfur fuels is not the ultimate answer. Some technological development for control of emission or of the sulfur in the fuel is going to be necessary.

We feel that the public health officials, and many of them have done this, have gone out of their way to emphasize the need for control of the problem through the use or offering, say, two-tenths of 1 percent sulfur coals and these coals are not available. It does not appear to us that the approach has been realistic in the light of the available knowledge.

We are fearful that they will continue to advocate low emission limits by control of sulfur in fuels. Such limits sometimes are not

really required and without low sulfur fuels available you are going to wind up with exceptions to rules and regulations.

This is why we feel a national standard on emissions is not realistic at this time. You are going to have a national standard for each powerplant in order to be able to control emissions and this is not very realistic to us.

Senator MUSKIE. Then what separates you on the question of substitute fuels is the factual question of whether such fuels are actually available, at least fuels sufficiently pure to meet the standards which they suggest are sufficiently available. That is the question that separates you.

Mr. GARVEY. Yes.

Senator MUSKIE. All right.

Mr. GARVEY. Well, the fact is that this year we will consume 280 million tons of coal in our plants which, based on past records, over 80 percent will contain in excess of 1 percent sulfur.

I think the testimony that has already been presented to the committee is that our low sulfur fuels such as gas, oil and coal are not sufficient to satisfy the current and future demands for fuel for the electric energy market which is doubling each 10 years and expected to do so for the next 30 years.

Senator MUSKIE. May I interrupt you, Mr. Garvey, to ask whether it is possible to provide for the record (1) an analysis of the coal reserves that are available in terms of sulfur content; and (2) an analysis of the production of coal that is now going into the market on the basis of sulfur content so that we may have some notion of the quantities that are available, where they are available, and the extent to which they are now being produced?

Mr. GARVEY. Yes, sir; we can do that.

(Subsequently, Mr. Garvey transmitted the following communication:)

BITUMINOUS COAL RESEARCH, INC.,
Pittsburgh, Pa., May 25, 1967.

Hon. EDMUND S. MUSKIE,
Chairman, Subcommittee on Air and Water Pollution,
U.S. Senate Committee on Public Works,
Washington, D.C.

DEAR SENATOR MUSKIE: At the May 16, 1967 hearings of the Subcommittee on Air and Water Pollution, Committee on Public Works, United States Senate, you asked that I submit testimony regarding the availability of low-sulfur coals. Your question, phrased as it was, requesting information on both reserves and production of coal on the basis of sulfur content, was most appropriate. It is important that, when we consider the possibility of substituting low-sulfur coals for the high-sulfur coals now being used for the generation of electric power, we take account of not only the reserves estimated to be available but also the location of those reserves in relation to the market and the location of currently producing mines.

Let us first define low-sulfur coal. In recent hearings, Public Health Service officials have suggested the substitution of coals having less than 0.3 percent sulfur content. To our knowledge, there is no information available on the reserves of coal having sulfur content this low, and it is concluded that reserves of such coal are so small as to be negligible. This conclusion is supported in a letter dated January 5 to Senator Jennings Randolph from the Director of the Bureau of Mines, Walter R. Hibbard, in which he stated in regard to such coals, "Regardless of price, there are no significant quantities of coal available which could meet these sulfur limits."

In general, low-sulfur coals are referred to as those having 1.0 percent sulfur or less. For further discussions we will therefore consider any coal 1.0 percent

or less to be low-sulfur, and any coal higher than that number to be high sulfur.

In 1966, the Bureau of Mines published Information Circular 8312 entitled "Sulfur Content of United States Coals." This publication was made a part of the official record of the Subcommittee hearings on May 9, 1967. This is the most complete tabulation of reserves and production of coal by various sulfur content categories that has been produced. The accuracy of the data on coal reserves has been questioned because no consideration has geen given to thickness of seam, conditions of mining, area of coal available in a given site, depth of cover, dedication of selected portions for fulfillment of contracts already consummated, and other factors. Nevertheless, it is an available tabulation and presents a basis for analysis in reply to the question you raised.

The first impression obtained from a review of the data included in USBM Information Circular 8312 is that tremendous reserves of low-sulfur coal exist. That such is the case for all coals in the United States is undeniable. But an analysis of the production capacity and the availability of these coals in terms of geographic location with relation to the market presents an entirely different picture.

The tabulation in Table A-1 of the Circular lists all types of coals in the United States. The subbituminous coals and lignite comprise 77 percent of the low-sulfur reserves but they are for the most part located in the western states and far removed from coal-market areas. Transport of these coals to the present markets is not economically feasible. Anthracite is of limited quantity and mineable at only a high cost. In addition, the subbituminous, lignite and anthracite coals, which account for 79 percent of the U.S. low-sulfur reserves, comprise only 4 percent of the coal productive capacity of the U.S. For these reasons these coals can be dismissed from present consideration.

Bituminous coal accounts for 96 percent of current production capacity and 21 percent of the low-sulfur reserves. Because of location near the market it is used by the electric-utility and other industries. So, let us consider only the bituminous coals and the information published in the USBM circular relating to their availability and production.

For discussion purposes, we will divide the bituminous coal data into three groups by states. These groups will be defined as follows:

Group I. Comprising the western states of Alaska, Arizona, Arkansas, California, Colorado, Idaho, Montana, Nebraska, Nevada, New Mexico, Oklahoma, Oregon, Utah, Washington, and Wyoming.

Group II. Comprising the states of Alabama, Eastern Kentucky, Virginia, and West Virginia.

Group III. Comprising the states of Illinois, Indiana, Iowa, Kansas, West Kentucky, Maryland, Missouri, Ohio, Pennsylvania, and Tennessee.

The following tabulation prepared from data contained in USBM Circular 8312 presents a clear picture of the relationship of location of low-sulfur bituminous coal reserves to current production.

	Percent of total production [1]	Percent of low sulfur reserves	Percent of low sulfur production
Group I	3.6	61.6	9.0
Group II	48.2	36.9	90.1
Group III	48.2	1.5	.9

[1] Include both high-and low-sulfur coals.

As can be seen from the table, the major portion of the reserves of low-sulfur bituminous coal are in the Group I states. However, these reserves, situated as they are in the western states, are, like the reserves of lignite and subbituminous coals, located so far from the market areas as to preclude their use as a substitute for the high-sulfur fuels. Also, it can be seen that of the total productive capacity of the bituminous coal industry, a very small portion, only about 3.6 percent, exists in the Group I states.

The Group II states comprise the major low-sulfur bituminous coal-producing areas of the United States. These states have about 37 percent of the total low-sulfur bituminous coal reserves, and 96 percent of the low-sulfur bituminous coal reserves located east of the Mississippi River. The coal seams are con-

centrated in a very limited geographic area, mostly at the juncture of the states of Virginia, West Virginia, and Kentucky, plus a small amount in Alabama.

The limited geographic area in which these reserves are located is even more restricted than is readily apparent from the USBM Circular data because the reserves for the northern and southern portions of the State of West Virginia are not separately tabulated. But by analyzing the productivity of that State's counties, one can get a clearer picture; the Southern sector contains the major low-sulfur coal-producing mines. Allowing for this, we find that the area at the junction of Virginia, West Virginia, and Kentucky, plus Alabama, accounts for 86 percent of the low-sulfur bituminous coal production of the United States.

In addition to being low sulfur, these coals also have another important characteristic, namely, their usability for the production of metallurgical coke. Because of these two characteristics, a major portion of the coal produced by the Group II states is used for metallurgical purposes and does not enter the steam market. In general, the coal seams are thin and production by deep mining is necessary. For this reason, the coals produced in the Group II states cost as much as 78 percent more per ton at the mine. (Example: for 1965, f.o.b. mine value for District 7 coal was $5.87 compared to $3.31 for District 9 coal.)

The Group III states are the major producers of steam coal. But they have limited low-sulfur coal reserves amounting to only about 1.5 percent of the low-sulfur bituminous coal reserves of the country. Based on current production of these states, this amounts to about a 7-year life index. On the other hand, these states contain an estimated total of 414 billion tons of high sulfur, but otherwise quality steam coal which is located near the market and can be mined at low cost. This is enough coal to provide a supply for over 1000 years at current production rates.

From this analysis of the data available on low-sulfur coal reserves and production of the United States, several conclusions can be drawn:

1. Because of their location in relation to the market and the production capacity available (currently about 4.0 percent of the U.S. total), the reserves of low-sulfur coals located in the western states must be considered unavailable as a substitute for high-sulfur eastern coals.

2. The low-sulfur bituminous coal reserves in the eastern part of the United States are located in a relatively small pocket in the Southern Appalachian region. The coals from this area are also the source for most of the metallurgical coal produced in the United States and much of the reserve is dedicated for this.

3. Because of the aforedescribed location of low-sulfur coal reserves and the relation of these reserves to current production, an arbitrary decision to restrict the use of coal to that containing 1.0 percent sulfur, or less, would have a tremendous social and economic impact.

a. Since the states of Illinois, Indiana, Iowa, Kansas, Western Kentucky, Maryland, Missouri, Ohio, Pennsylvania, Tennessee, and Northern West Virginia have practically no reserves of low-sulfur coals (the largest is Pennsylvania with a life-reserve index of six years), *all coal-mining operations in these states and parts of states would be discontinued.* The current bituminous production from these areas amounts to almost 50 percent of the United States total.

b. To satisfy the demand for coal, production capability amounting to about 285 million tons per year, would have to be relocated. Since the investment in a coal mine and associated facilities amounts to about $10 per ton of annual production, this would mean the abandonment of almost three billion dollars worth of investment and the added investment of a like amount in new facilities.

c. The effect on transportation facilities for moving coal from the mines to the market would be chaos. Some railroads, such as those in Illinois and Indiana, would lose as high as 85 percent of their revenue, and other railroads in the eastern part of the United States, which receive a major share of their revenue from coal haulage (for instance, the Norfolk and Western, 41 percent, and the Chesapeake and Ohio, 49 percent) would have to relocate miles of haulage facilities.

d. Of perhaps the most serious concern is the potential impact on the communities where coal is now mined. A recent study (by Operations and Policy Research, Inc., for the National Coal Association, National Coal Policy Conference, and the United Mine Workers of America) shows the economic impact of the coal industry on the economy of coal-producing states. By using this informa-

tion we can conclude that the losses in wages spent to communities in the states of Illinois, Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia would total about 1.1 billion dollars annually.

In light of the foregoing, it does not appear practical to assume that the substitution of low-sulfur coals for air pollution control will be any more than a temporary expedient in critical areas.

Sincerely yours,

JAMES R. GARVEY,
President and Director of Research.

Mr. GARVEY. Now, I as I mentioned earlier, in response to your first question, it is possible in certain critical areas to use low-sulfur fuels, but not for the long-range future for meeting the power demand of the United States.

Some have said that we can substitute nuclear power but even those who predict nuclear power growth, anticipate that the utility coal consumption will still grow.

As Congressman Melvin Price pointed out in his testimony before this committee on May 9:

> Fossil fuel and the atom may be competitors, but for the foreseeable future they must also be partners in furnishing America's need for electricity.

A reputable trade publication, Electrical World, has recently predicted that coal consumption for power generation will grow from the current 280 million ton annual rate to 450 million in 1975, and to 550 million in 1980.

We expect that by the end of the century consumption will near the 900 million ton level. The conclusion is apparent that if we are to satisfy the growing energy demands of our Nation, we must use our high-sulfur coals. How to do this and still minimize pollution of our atmosphere is the research problem which faces us.

While the purpose of the testimony today is to review methods for control of emissions of sulfur oxides, some discussion of the degree of emission control necessary is appropriate. It is important that we relate control of emission of pollutants to the deterioration of air quality caused by such pollutants.

From a health standpoint, we are not concerned with the sulfur in the fuel or sulfur oxides being emitted from the top of the stack. Of concern to us is the concentration of pollutants in the air which man breathes and to which plants are exposed. Or, as it is called, the quality of the ambient air.

Other witnesses have brought to this committee's attention the diverse opinion among many experts, including medical experts, regarding what the quality of such ambient air should be. I will not burden the committee with additional comment on this except to say that I am as confused as most people are who have compared the medical literature pertaining to the health of sulfur oxides with the recommendations of some public health officials.

After listening to this testimony, I am not embarrassed as an engineer to say I am confused.

However, assuming that it is scientifically determined that a given maximum level of sulfur oxides in ambient air is desirable, it does not necessarily follow that the most realistic way to achieve this is by establishment of an emission standard. Such an approach disregards many factors such as height of emission, meteorologic and geographic conditions, and the presence of other pollution sources.

Therefore, this discussion on the state of the art would not be complete without including all possible approaches to control of pollutants; or, in other words, we should not restrict our discussions to control of emissions, but should concern ourselves with the real problem, the control of the ambient air quality, whatever it is concluded that that quality must be.

What are the means available to us for minimizing the deterioration of ambient air quality by emissions of sulfur oxides from power generating stations? We have already pointed out the severe limitations on the most obvious solution, the use of substitute low-sulfur fuels. And, as requested by Senator Muskie, we will submit this material for the record on this subject.

And, although the testimony you will hear today will indicate that research has advanced the development of processes for control of sulfur oxide emissions with high sulfur fuels, the fact remains that at the present time there is no process which has been demonstrated, on a commercial scale, to be usable for control of the sulfur oxide emissions resulting from the use of these high-sulfur fuels, coal, and oil. Please note that I have made no reference to cost—we do not yet have a process available at any cost.

I believe that today you will hear about some processes which are nearing the point of demonstration of technical feasibility, and I will go into that and talk about a couple we are working on. However, large-scale tests of these processes will be needed for final determination of their effectiveness and cost. We will discuss this in more detail later.

Senator MUSKIE. Since we do not have the technology available to control stack emissions or to reduce the sulfur content of fuel below the point where it is controlled in connection with the ore, I take it there is no technology available to reduce the sulfur content of coal.

Mr. GARVEY. I will tell you a little bit about what we are doing on that. There is some available.

Senator MUSKIE. That being the case, the only two ways that have been suggested in the record here to deal with a sulfur problem in an area where there is air pollution is either to substitute low sulfur content fuels or to relocate the offending plant? Is that about it?

Mr. GARVEY. I believe that is a fair statement if we assume that we are talking about control of emissions.

Now, if you are talking about control of ambient air quality, I think we have to add another one, one that was discussed here last week, and that is the use of high stacks or other means of dispersing the pollutants.

Senator MUSKIE. All right.

Mr. GARVEY. As I say, you will hear about some processes which are in advanced stages of process today and I think you will agree we are moving toward our objective.

Our primary concern is that perhaps we are moving too fast in the imposition of control measures or we are moving faster than the technology is developing.

I hope you will get the impression from the presentations today that the technology is moving along and, if we take a realistic approach, we may attain everybody's objective.

While low-sulfur fuels are limited in supply, and there is no known commercial process for the reduction of emissions from high-sulfur coals, there is available means for control of ambient air quality. This is through the use of properly designed stacks. The use of this tool for control of the effects of powerplant emissions of sulfur oxides on ambient air quality was testified to last week by witnesses from the Central Electricity Board of England.

Messrs. Clarke and Stone pointed out that their intensive studies had conclusively shown that sulfur oxide emissions from high stacks were not contributory to the several severe air pollution episodes experienced in their country. As they pointed out, even under adverse weather conditions, the plumes of powerplant stacks pierced the inversion layer and permitted dispersal of pollutants.

A tremendous amount of research has been done on the effectiveness of high stacks in the past several years in both the United States and in England. This research has included wind tunnel studies with models, and correlation of the data obtained with studies of the dispersal of plumes from stacks of varying heights and under varying meteorologic and geographic conditions.

From this work, formulas have been derived which enable predicting with astonishing accuracy the amount of pollution which will be contained in the ambient air as a result of given emissions at the top of the stack. A properly designed stack is, therefore, a very effective tool in the control of ambient air quality.

This research on the bahavior of stack plumes and the dispersal of the pollutants contained therein is continuing. The U.S. coal industry, through the research organization which I represent, has joined with the American Petroleum Institute, the Edison Electric Institute, and the Public Health Service research branch in the sponsorship of a special project which started in mid-April of this year.

This investigation, which will be carried out by CCA Laboratories of Boston, Mass., will seek further detailed information on the fate of sulfur oxides from the time they leave the top of the stack until they become a part of the ambient air several miles away.

Laboratory studies and careful sampling of stack plumes, through the use of airplanes, will be conducted in an effort to provide much needed information on what happens to the sulfur oxides after they are discharged to the atmosphere.

In addition, we have had several discussions with the laboratories of the Atomic Energy Commission; after consultation with coal scientists, the Atomic Energy Commission is investigating the feasibility of using a radioisotope of sulfur to trace the dispersal of sulfur compounds from a given stack and to determine the contribution of the emissions from that stack to ambient air quality.

I cite the foregoing information regarding stacks, and the research related thereto, because I believe that the research on stack dispersal of pollutants which has been done in the past several years has contributed to an advancement in the state of the art related to control of ambient air quality.

In addition, utility companies are already using this information and incorporating it into the design of their new plants. Stacks upward of 700 feet in height are already in use, and higher ones are contemplated.

In concluding this brief discussion of emissions versus ambient air quality control, I want to emphasize again that the emission from a given plant is not the most important factor to be considered; rather, the contribution of those emissions to ambient air quality is the significant concern.

It is obvious that a large generating station located in New Mexico and miles from any urban or industrial development can emit greater quantities of pollutants without affecting the ambient air quality than can a similar power station located in the Eastern part of the United States, near or in our highly industrialized cities.

Therefore, the establishment of a minimal national standard for sulfur oxide emission does not appear to be practical.

Senator MUSKIE. Let me ask you this, Mr. Garvey.

What you have just said really touches the heart of the argument, the national emission standards. If this is the fact, and it is a fact, then it seems to me that it can lead to the threat which is made that control in an area where there ought to be control by any objective standard would or could mean the relocation of the industry involved.

Now, I visited a city, which I am not going to name at this point, in which it is quite clear that the threat of relocation underlines the community attention being focused on the air pollution problem and that the community is inhibited in dealing with it.

Now, what do you do in a situation of this kind? Here is a community where there ought to be some controls, where there is a severe air pollution problem. Yet quietly the word is passed, "Now, look, you better take it easy; you better not talk too much about it and give this community a reputation which would drive industry away, or if you are too tough with us there are plenty of other places where we can move."

Now, what do you do about a situation like that, Mr. Garvey?

Mr. GARVEY. Speaking as an engineer, I don't believe I can tell you how to handle community relations but it appears to me——

Senator MUSKIE. No, but you are a citizen and this is a problem citizens have to face.

Mr. GARVEY. I believe, speaking as a citizen and even speaking as a representative of the coal industry, this is an unrealistic approach for a community or a plant therein to take.

If there are available means for control of pollution, these means should be applied. Whether the plant intends to move out should not be a part of the argument if the means is available.

Now, as I say, in critical areas where the technology is available to do the job with control of emissions or control of pollutions, I don't believe the coal industry should take that position, and I don't think they have taken the position that plants should move. They will do everything they can to provide means for control of pollutants for a given plant and recommend control methods to make that plant acceptable to the community.

Senator MUSKIE. Let me ask you another question. I interrupt only because I do have to leave even though I don't like to interrupt a witness in the course of his prepared testimony.

Now, a distinction has been suggested between national emission standards and minimal national emission standards. In other words,

it is argued that what we are talking about, though we speak of national emission standards, is a minimal emission standard that everybody can live with and that can be upgraded in situations where air pollution is critical enough to require it by local authority.

Now, what is your understanding of the distinction between national emission standards, which initially I would think of as the standards that met the ultimate, and minimal standards?

Does this distinction mean anything to you that you can identify?

Mr. GARVEY. Well, frankly, I am a little confused on the various means or various wordings.

(Subsequently, Mr. Garvey submitted the following communication and exhibit in response to the foregoing request:)

BITUMINOUS COAL RESEARCH, INC.,
Pittsburgh, Pa., May 29, 1967.

Hon. EDMUND S. MUSKIE,
Chairman, Subcommittee on Air and Water Pollution,
U.S. Senate Committee on Public Works,
Washington, D.C.

DEAR SENATOR MUSKIE: This is in reply to a question which you asked me when I appeared on May 16, 1967, as a witness before your Subcommittee. The question was as follow (Transcript, page 987):

"Now, a distinction has been suggested between national emission standards and minimal national emission standards. In other words, it is argued that what we are talking about, though we speak of national emission standards, is a minimal emission standard that everybody can live with and that can be upgraded in situations where the air pollution problem is critical enough to require it by local authority.

"Now, what is your understanding of the distinction between national emission standards which initially I would think of as the standards that met the ultimate and minimal standards?"

With the many variables which exist, the inability to accurately measure pollutant concentrations and the limited knowledge regarding their effects, it is difficult to conceive how minimal national emission standards could be determined and implemented for stationary plants. Although the Public Health Service is advocating the establishment of such standards, they seem to recognize the difficulties which will be involved. This was indicated by the statement of Dr. John Middleton in his testimony before your subcommittee on April 19 when he said:

"Air quality standards are prescriptive; they prescribe pollutant levels that cannot legally be exceeded during a specific time in a specific geographic area."

This statement seems to imply that different standards will be applicable to different areas of the country, and that even for a given area the standards might vary throughout the day. It appears that a multiplicity of standards will result which will create more confusion (instead of fulfilling the intent of any standard, which is to minimize confusion.)

For gaseous pollutants such as sulfur dioxide there appears to be insufficient finite information on which to base a standard. A means of measure is implicit in any standard and for many pollutants none is available. Certainly the measurement methods used for determining air quality criteria for sulfur oxides as described in the Department of Health, Education, and Welfare publication on this subject leave much to be desired. In the introductory pages of that publication the following statement pertaining to means for measure of sulfur oxides appears:

"Sulfur dioxide is most commonly measured by the West-Gaeke or hydrogen peroxide technique, or by electroconductivity. The West-Gaeke technique underestimates the true concentration of sulfur dioxide in the presence of ozone or nitrogen dioxide or salts of heavy metals—the hydrogen peroxide technique may give either high or low values depending upon whether there is an excess of basic or acidic gases or particulates other than sulfur dioxide present in the air. Usually the values obtained by this method are intermediate between those obtained by the West-Gaeke and electroconductivity techniques. Electrocon-

ductivity methods may give values one to five times higher than, but usually less than twice as high as, those obtained by the West-Gaeke technique because with electroconductivity methods other soluble gases yield electrolytes in solution and these electrolytes can cause high measurements. Sometimes, however, alkaline gases, such as ammonia, which neutralize the acid, are present to the extent that values below those yielded by the West-Gaeke technique result."

It is difficult to comprehend how even an "Air Quality Criteria for Sulfur Oxides" could have been developed on this basis—a national emission standard just does not seem possible.

Of all the pollutants, perhaps the control of particulates comes the closest to being suited to standardization. Yet even here there will be difficulties. In your question you mentioned 95 percent versus 99 percent efficiencies of collection and asked about the possible use of the former as a minimal standard. Such an approach oversimplifies the control problem and overlooks several variables.

It is possible for a plant having 99 percent collection efficiency to emit and to deposit more particulates around the plant area than one having 95 percent collection efficiency because the dust loading of the gases entering the collectors is not considered nor is the height from which the particulates are emitted. If the plant with 99 percent collection efficiency has ten times the dust loading of the plant with 95 percent collection efficiency, the dust discharged from the more efficient collectors will be twice that from the other. And if the plant with the lower collection efficiency is equipped with a high stack, while the other is not, the difference in particulate deposited by the two plants will be even greater.

A more effective approach to a usable standard for particulate control is illustrated by the "Recommended Guide for the Control of Dust Emission—Combustion for Indirect Heat Exchangers" published by the American Society of Mechanical Engineers, a copy of which is enclosed. But even this excellent publication, developed through the cooperative effort of industry and government, is not suggested by the authors as a national standard. The "Limitations" are given on page 7.

It is apparently the objective of the proposed use of national standards to cause all industry to utilize the most current pollution control technology available where an air pollution problem exists. This objective is one we endorse; we only question whether the promulgation of emission standards is the best approach. Perhaps a more effective method would be for the national air pollution control agency, with the counsel and cooperation of industry, to proceed as follows:

1. To define by industry source and by pollutant the capability for control based on known technology. These definitions could take the form of recommended guides for control such as the enclosed ASME publication and,

2. To define how this capability for control of specific pollutants should be applied for a given area, including such factors as the interaction with other pollutants, presence of other sources of the same pollutant, topographic features, normal and abnormal weather conditions, etc.

In the first step suggested above regarding the capability of control, special technical committees could be set up on a national basis. Included on the committees should be nationally known experts on control of specific pollutants for certain industries as well as government experts. Precedent for this approach has already been established in the development of the enclosed ASME dust control guide. The special committees could review the state of the art of control of the various pollutants and prepare technical guides for use by industry and government in pollution abatement.

I recognize that the question will arise, "What is the difference between a guide and a standard?" This may only be a matter of interpretation but to me a standard implies rigidity established on a sound technological base; a guide is broader and more flexible.

In the second step, definition of the required degree of application of control capability, special industry and government committees could again be used but their composition should be of a local nature and representative of the community or area in which the air pollution control problem exists. Using the prepared guides and considering the other variables present in the local community, these committees could produce recommendations for air pollution control regulations for the community which could be enforced by local government. In this manner each plant, be it steel mill, power plant, chemical plant, or other, would be required to comply to that degree of control which will provide satisfactory ambient air quality for that community.

77-515 O—67—pt. 4——13

The afore described procedure would, of course, leave the ultimate enactment of regulations and their enforcement to local officials. The fear has been expressed that local industry will through political coercion and/or threats to move away, influence local officials. This we do not believe. There are examples of cities in this country in which startling improvements in air quality have been achieved by intelligent cooperation between local industry and local government without federal intervention. I can cite no better example than the city in which I reside, Pittsburgh. While perfection has not been attained, anyone living there today who lived there twenty years ago will attest to the remarkable improvement.

It is realized that the matter of the pollutants from one community traveling to another will not be completely resolved by the foregoing. It is felt that with proper guidance by a national air pollution control agency, especially if that guidance is developed in full cooperation with industry, most communities will clean up their own air and this, in turn, will be beneficial to the other communities to which the air travels. But it is reasonable to assume that not all communities will voluntarily comply. When this occurs, we would suggest procedure somewhat along the following lines:

1. If a community has, by application of principles set forth in the aforementioned emission control capability guides, demonstrated that it has under control *all* the pollutants emitted within its boundaries, and if this community feels its air is being adversely affected by emissions from another community, it could appeal through the appropriate state machinery to a national air pollution control agency.

2. The national agency would then survey the situation, determine in public hearings the degree of compliance with accepted control measures by the offended community, and the extent to which the pollutants of the offending community are affecting the air quality.

3. Following the survey and hearings at which both offender and offended, and other parties affected, would be heard, decision would be reached as to what action is necessary and feasible. Such action could include requiring the offending community to have installed the necessary pollution control means available and as defined in the capability guides.

However, the need for control of *all* pollutants is emphasized. Despite the criteria for sulfur oxides published by the Department of Health, Education, and Welfare, there has been sufficient testimony by expert witnesses at the recent meetings of the subcommittee to demonstrate a lack of conclusive evidence that any single pollutant in concentrations normally found in ambient air is harmful. But all seem to agree that there does exist a combination of pollutants (a combination as yet unknown) which does affect health. Therefore, it appears logical that the effort for improved air quality should be directed to all pollutants and not at any selected one. To me, it appears somewhat ridiculous, in light of this prevailing evidence on the possible health effects of pollution combinations and the indication that particulates may be the most important, for one community to complain that the sulfur oxides from an adjacent community are polluting its air when, within the confines of the complaining community, city-owned incinerators are spewing tons of particulate matter into the air each day.

In summary, it is our belief that national emission standards in the accepted sense of the word are not feasible. A national pollution control agency, however, could contribute to the national air pollution control effort by (1) preparing guides which define the capability for pollution control; (2) carrying out and sponsoring research to improve control capability; (3) assisting local communities in defining the extent of their air pollution problem and developing regulations for use of control capability as needed to improve air quality; and (4) exercising responsible leadership in the resolution of inter-community disputes.

I realize that in attempting to answer your question I may appear to be writing legislation. Since I by no means feel myself qualified in this field, I want to assure you that this is not my intention. But I have tried as a representative of the coal industry and, as you suggested when I appeared before your subcommittee, "as a citizen," to outline what appears to me to be a reasonable approach which, hopefully, will help us to find practical solutions to this very difficult problem of air quality control.

Sincerely yours,

JAMES R. GARVEY.
President and Director of Research.

A S M E S T A N D A R D

Recommended Guide for the

CONTROL OF DUST EMISSION -- COMBUSTION FOR INDIRECT HEAT EXCHANGERS

ASME STANDARD
No. APS-1

Published by

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
United Engineering Center 345 East 47th Street New York, N. Y. 10017

Foreword

THIS standard on air pollution is an outgrowth of an Information Bulletin, "Example Sections for a Smoke Regulation Ordinance," prepared by the Model Smoke Law Committee, Fuels Division, The American Society of Mechanical Engineers, May 1949. It was recommended in that Bulletin that dust discharge to air in combustion gases should not exceed 0.85 lb per 1000 lb of combustion gases, adjusted to 50 per cent excess air for products of combustion (1.0 lb dust per million Btu input), except that a dust collecting efficiency of more than 85 per cent was not required. Because of an increase in discharge of waste materials to air brought on by an expanding population, the ASME Committee on Air Pollution Controls started a review of the Ordinance in 1959. This Committee was then chaired by G.V. Williamson, Union Electric Co., St. Louis, Missouri, and an Emissions Study Subcommittee was appointed. In 1962 the Smoke Regulation Ordinance was withdrawn from publication by ASME and the ASME Air Pollution Standards Committee was organized under the Board on Codes and Standards using the Emissions Study Subcommittee under the Board on Technology as the nucleus for the standards committee. The scope of the Air Pollution Standards Committee is as follows:

CODES AND STANDARDS ON THE EMISSION OF BOTH SOLIDS AND THOSE GASES NORMALLY THE CONCERN OF ASME (FROM COMBUSTION PROCESSES).

This first standard resulting from the work and deliberation of the Air Pollution Standards Committee was approved as a standard of The American Society of Mechanical Engineers by the ASME Safety Standards Committee and the ASME Board on Codes and Standards on June 15, 1966. Other standards within the scope of the committee are being developed.

Any part of this Standard may be quoted. Credit lines should read: "Extracted from ASME Standard, Recommended Guide for the Control of Dust Emission – Combustion for Indirect Heat Exchangers (ASME Standard APS-1), with the permission of the publisher, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, N. Y. 10017"

Copyright © 1966, by
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
Printed in U.S.A.

PERSONNEL OF ASME AIR POLLUTION STANDARDS COMMITTEE

F. T. Bodurtha, *Chairman,* Engineering Service Division, Engineering Department, E. I. du Pont de Nemours & Co., Wilmington, Delaware 19898
C. B. Vance, *Vice-Chairman,* Indianapolis Power & Light Co., 25 Monument Circle (*Mail:* P. O. Box 1595), Indianapolis, Indiana 46206
J. W. Mullan, *Secretary,* National Coal Association, 1130 – 17th Street, NW, Washington, D.C. 20036
C. A. Bishop, U. S. Steel Corporation, 525 William Penn Place, Pittsburgh, Pennsylvania 15230
R. L. Chass, Los Angeles Air Pollution Control District, 434 So. San Pedro Street, Los Angeles, Calif. 90013
F. W. Church, Esso Research & Engineering Co., P. O. Box 101, Florham Park, N. J. 07932
G. H. Damon, Office of Director of Coal Research, U. S. Bureau of Mines, Department of the Interior, Washington, D.C. 20240
W. L. Faith, 254 Huntington Drive, San Marino, Calif. 91108
L. P. Flood, Department of Air Pollution Control, New York City, 15 Park Row, New York, N.Y. 10038
W. H. Jaques, Engineering Division, Procter & Gamble Co., ITC Building, Cincinnati, Ohio 45217
W. H. Jukkola, Jones & Laughlin Steel Corporation, 3 Gateway Center, Pittsburgh, Pennsylvania 15230
E. C. Miller, Fuel Burning Division, Riley Stoker Corporation, 9 Neponset Street, Worcester, Mass. 01601
R. H. Pechstein, American Electric Power Service Corp., 2 Broadway, New York, N.Y. 10008
A. C. Stern, Division of Air Pollution, Public Health Service, U. S. Dept. of Health, Education, & Welfare, 3rd & C Streets, SW, Washington, D.C. 20201
J. B. Walker, Jr., Boiler Division, Babcock & Wilcox, Barberton, Ohio 44203
E. L. Wilson, Koppers Company, Inc., Metal Products Division, Scott & McHenry Streets (*Mail:* P.O. Box 298), Baltimore, Maryland 21203
L. A. Winkelman, Public Service Electric & Gas Co., 80 Park Place, Newark, New Jersey 07101

ACKNOWLEDGMENTS

F. J. Leonhard, Past Chairman and Past Member, The Cleveland Electric Illuminating Co. P. O. Box 5000, Cleveland 1, Ohio
A. H. Phelps, Engineering Division, Procter & Gamble Co., ITC Building, Cincinnati, Ohio 45217
D. B. Turner, Meteorologist, U.S. Weather Bureau, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio

Recommended Guide for the CONTROL OF DUST EMISSION -- COMBUSTION FOR INDIRECT HEAT EXCHANGERS

1. INTRODUCTION

There are three basic methods for controlling pollution of the air by waste materials. These are

a. Reduction in production of the pollutants

b. Collection of the pollutants

c. Dispersion of the pollutants in ambient air by air motion.

The final determinant is the concentration of the contaminant where it affects people or their property rather than the concentration at the site where the contaminant is emitted. The quality of the ambient air as desired by the community, or as required by the authorities, is, therefore, of primary importance in undertaking an air pollution control program. The desired or required quality of air can be obtained often by any one of the three methods indicated above. Usually, however, the objective is attained by a combination of two or more of them.

The manner of undertaking an air pollution control program, both its inception and its administration, by a community is beyond the jurisdiction of The American Society of Mechanical Engineers and, thereby, of this Standard. Nevertheless, the importance of cooperation among all citizen groups in the community, both private and corporate, in all stages of the undertaking, is emphasized. (See further, "Engineers Joint Council Policy Statement on Air Pollution and its Control," Report No. 107, 1957, Engineers Joint Council, 345 East 47th Street, New York, N.Y. 10017 – five cents per copy.)

2. SUSPENDED DUST

2.1 Method for Estimating Concentration in Ambient Air

The concentration of suspended dust in the ambient atmosphere is determined by the mass rate of dust emission, by the manner of discharge of the dust, and by subsequent dispersion (spreading) in the air. Meteorological dispersion equations are available to predict the concentration of suspended (airborne) dust. One of the classical equations is that of Bosanquet and Pearson [1]. More recent comprehensive treatment of the subject has been given by Pasquill [2], [3] and, using his treatment of the subject, Hilsmeier and Gifford [4] have prepared graphs for estimating atmospheric dispersion.

The philosophy has been adopted in this Standard that the maximum concentration of suspended dust in the ambient air from discharges is of primary importance when regulating ambient air quality. This maximum concentration at ground level will occur beneath the axis of a smoke plume during unstable or neutral atmospheric temperature conditions at some downwind location, and only at some "critical" wind speed that is usually moderate or high, and infrequent. As indicated earlier, the manner of discharge of the waste gas affects the concentration of suspended dust in the ambient atmosphere. Included in consideration of the manner of discharge is the physical stack height above grade and the rise of the plume above the stack tip. The latter depends on several factors, including wind speed, temperature of the stack gases, and momentum of the stack gases. Several investigators have developed methods to predict this rise. These have been summarized by Moses, Strom and Carson [5].

Two different methods of determining the maximum concentration of suspended dust at ground are covered in detail in Appendix A. The dispersion equations and graphs in sections 1 and 2 of Appendix A are the basic part of this standard. The effective height of emission (stack height above grade plus plume rise for any specified conditions) is included in the equations and graphs. There is divergence in calculated plume rises from the several formulas given in Ref. [5]. The formula of Lucas, Moore and Spurr [6] has been used in this Standard to calculate plume rise that is part of the effective height of emission. This represents good engineering practice at present. The basic dispersion equations and graph (Fig. 3), however, can be used with any plume rise formula. Because

ASME STANDARD – GUIDE FOR CONTROL OF DUST EMISSION

of some possible inaccuracies in the Lucas plume rise formula, certain fractions of the theoretical rise, less than unity, have been used for heat inputs of less than 4000×10^6 Btu/hr. These are tabulated below.

Total Heat Input (Btu/hr)	Plume Rise Formula
Equal to or more than 4000×10^6	Lucas with 12% of total heat input up chimney
Less than 4000×10^6	Specified fraction of Lucas with 12% of total heat input up chimney, as follows: 1. 67% of Lucas for stack heights 150 ft and less 2. 80% of Lucas for stack heights 225 and more

The two dispersion equations just discussed and covered in detail in Sections 1 and 2 of Appendix A give similar values of maximum suspended dust concentration. Figs. 1 and 2 have been constructed using the results of Appendix A. Fig. 1 is for a maximum suspended dust concentration of about 200 micrograms/cu m for 3-15 minutes; Fig. 2, for about 100 micrograms/cu m for the same period (stack height in Figs. 1 and 2 refers to physical stack height). Concentrations will be considerably less for longer periods, according to the table below.

Time Period	Concentration (3-15 min. = 1)
30 min. to 1 hr	½
24 hr	¼

Either Fig. 1 or Fig. 2 could be selected by a community or used by a power station, depending on its desires or requirements in relation to ambient air quality. It should be noted that the concentrations given in Figs. 1 and 2 will be above the background level of suspended dust at "critical" wind speeds. These are usually moderate or high, *not low*, wind speeds. Therefore, if background values of suspended dust are used in conjunction with Figs. 1 and 2, those values should be for moderate wind speeds.

2.2 Collection Efficiency

Examples of dust collection efficiencies required for specified dust emission from combustion of pulverized coal are given in the following table.

Dust Emission (lb/million Btu input)	Required Dust Collector Efficiency (%) A*	B**
1.0	84.60	91.66
0.8	87.80	93.30
0.6	90.80	95.02
0.4	93.88	96.70
0.2	96.71	98.33

* A is for 13,000 Btu, 10 per cent ash coal, with 85 per cent of ash fired entering the collector.
** B is for 10,000 Btu, 15 per cent ash coal, with 80 per cent of ash fired entering the collector.

Equipment selection will depend upon the desired or required collection efficiency, as determined by Figs. 1 or 2. With present-day practice the maximum attainable collection efficiency with a high efficiency mechanical collector on dust from firing of pulverized coal is 85 per cent. The maximum collection efficiency with a high efficiency mechanical collector on dust from coal firing by spreader stoker is about 90 per cent. The dust collection efficiency using an electrostatic precipitator can be as high as 99.9 per cent. Costs for an electrostatic precipitator increase significantly as collection efficiency increases, as indicated in the table below.

Collection Efficiency (%)	Relative Installed Cost (Approximate) for Electrostatic Precipitators
90	1
95	1.3
97	1.5
98	1.7
99	2.0
99.75	2.6
99.9	4.7

2.3 Several Stacks

A power station complex often has several stacks. The abscissa in Figs. 1 and 2 is the equipment capacity rating for the total plant from

which plumes merge close to that plant. This will most often be the case for a modern power plant. Corrections are needed to account for less plume rise when the hot gases are discharged through several stacks. As shown in Appendix B, D (dust emission) in Figs. 1 and 2 must be divided by $n^{0.25}$ where n is the number of stacks of equal height. This assumes further that the emission is divided equally among the n stacks. This may not always be the case. The use of Fig. 1 or Fig. 2, together with the concept discussed in Appendix B, will, in such cases of inequality, form a constructive base for decision.

Some minimum collection efficiency is needed to prevent problems from settleable dust, which is discussed in Section 3. Therefore, 0.8 lb dust/million Btu input is recommended as a maximum emission from any stack, irrespective of stack height. This is a reduction from the withdrawn and now outmoded ASME 1949 Smoke Regulation Ordinance. D in Figs. 1 and 2 may calculate to be more than 0.8 lb dust/million Btu input for the total equipment capacity rating when two or more stacks are used. In all cases, however, actual emission must be 0.8 lb/million Btu input, or less, for each stack.

2.4 Limitations

2.4.1 *Area Sources*

When numerous sources, particularly low-level, in a confined area are involved, the highest ground level concentrations most likely will not occur with moderate to high winds but with low wind speeds together with stable atmospheric temperature conditions (temperature inversion). There may be some areas in which a lower maximum than 0.8 lb dust/million Btu input is needed. This depends on many factors, including:

a. The topography and the meteorology of the area.

b. The number and variety of dust sources.

c. The height and manner of discharge.

d. The existing concentration of dust at ground level.

e. The desires of the community.

It is not likely that any one "cap" can take all these factors into account. Either Fig. 1 or Fig. 2 and the "cap" at 0.8 lb dust/million Btu input can aid many communities and regions in arriving at effective dust control methods. Nevertheless, a "cap" that is suitable for one location may not be strict enough for another, and what is needed in one location may be unnecessary in another.

2.4.2 *Other Requirements on Stack Height*

As already indicated, the maximum concentrations of suspended dust at ground level from emissions from elevated stacks will usually occur at moderate or high wind speeds. Where a stack rises from or is adjacent to a high large building, its height (above grade) should be at least 2 to 2½ times the height of the building, where practicable, to avoid downwash of the plume.

Also, it will often happen that discharge of sulfur dioxide, not dust, will govern the required stack height. In such cases the stack height so required would be used as an independent variable in accompanying Fig. 1 or Fig. 2. The dust emission (D), or collection efficiency that gives 200 or 100 micrograms/cu m, then, can be determined from the figures.

2.4.3 *Valleys*

The methods on determining the concentration of suspended dust that have been discussed heretofore may not give reliable results when applied to confined valleys. The reason for this are primarily two-fold, as follows:

a. Strong temperature inversions in valleys that prevent attainment of plume rise that would result otherwise.

b. Trapping of fumes by valley walls.

These effects will be most pronounced at low wind speeds. It is probable in the case of the confined or narrow valley that additional consideration on concentrations of suspended dust is necessary. Less dust emission (lb/million Btu input) than indicated in Figs. 1 and 2 may be necessary, other things being equal, to give the concentrations indicated therein. Some other alternates are to install higher stacks than would be determined from Figs. 1 and 2 or to discharge the stack gases hotter than normal during certain specified weather conditions of low wind speed, together with a strong temperature inversion.

3. DUST DEPOSITION

The rate of dust deposition from a stack depends on several factors, particularly the

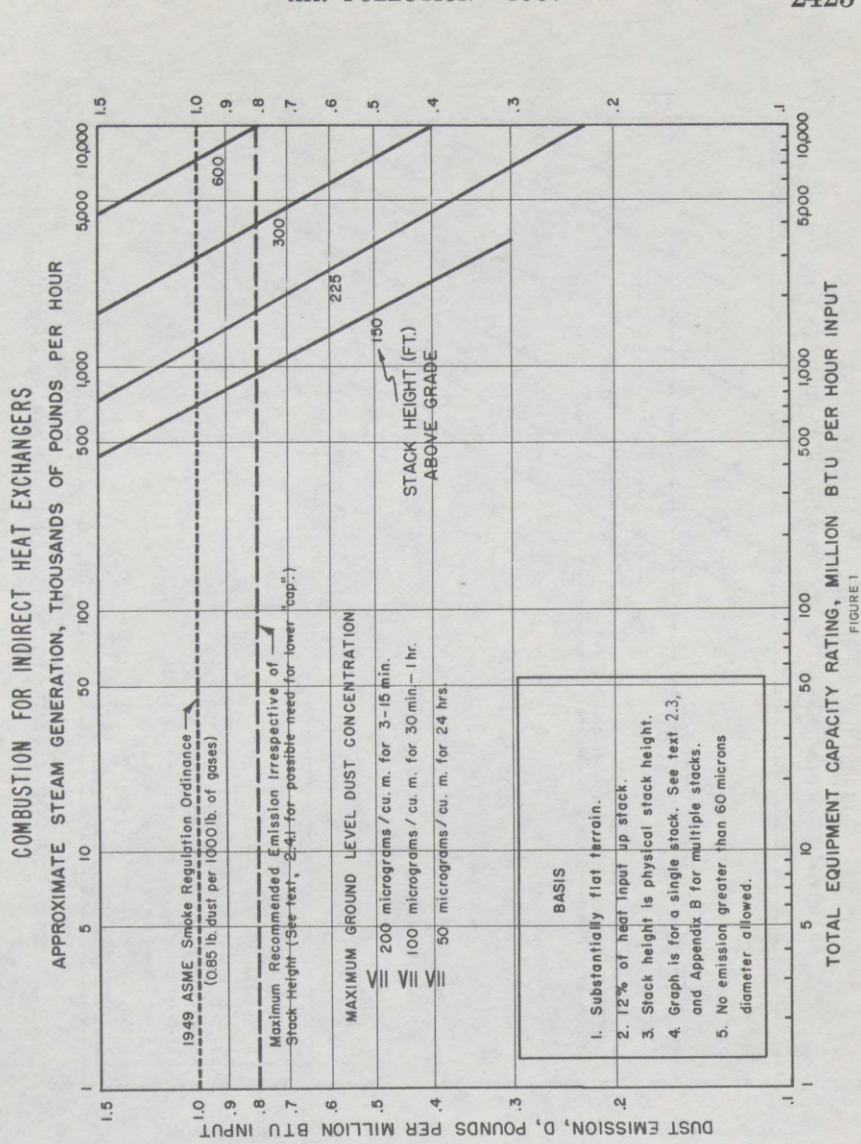

COMBUSTION FOR INDIRECT HEAT EXCHANGERS
APPROXIMATE STEAM GENERATION, THOUSANDS OF POUNDS PER HOUR
1949 ASME Smoke Regulation Ordinance
(0.85 lb. dust per 1,000 lb. of gases)
Maximum Recommended Emission Irrespective of Stack Height (See text, 2.41 for possible need for lower "cap".)
MAXIMUM GROUND LEVEL DUST CONCENTRATION
200 micrograms / cu. m. for 3-15 min.
100 micrograms / cu. m. for 30 min.-1 hr.
50 micrograms / cu. m. for 24 hrs.
STACK HEIGHT (FT.) ABOVE GRADE
600
300
225
150
BASIS
1. Substantially flat terrain.
2. 12% of heat input up stack.
3. Stack height is physical stack height.
4. Graph is for a single stack. See text 2.3, and Appendix B for multiple stacks.
5. No emission greater than 60 microns diameter allowed.
DUST EMISSION, D, POUNDS PER MILLION BTU INPUT
TOTAL EQUIPMENT CAPACITY RATING, MILLION BTU PER HOUR INPUT

FIGURE 1

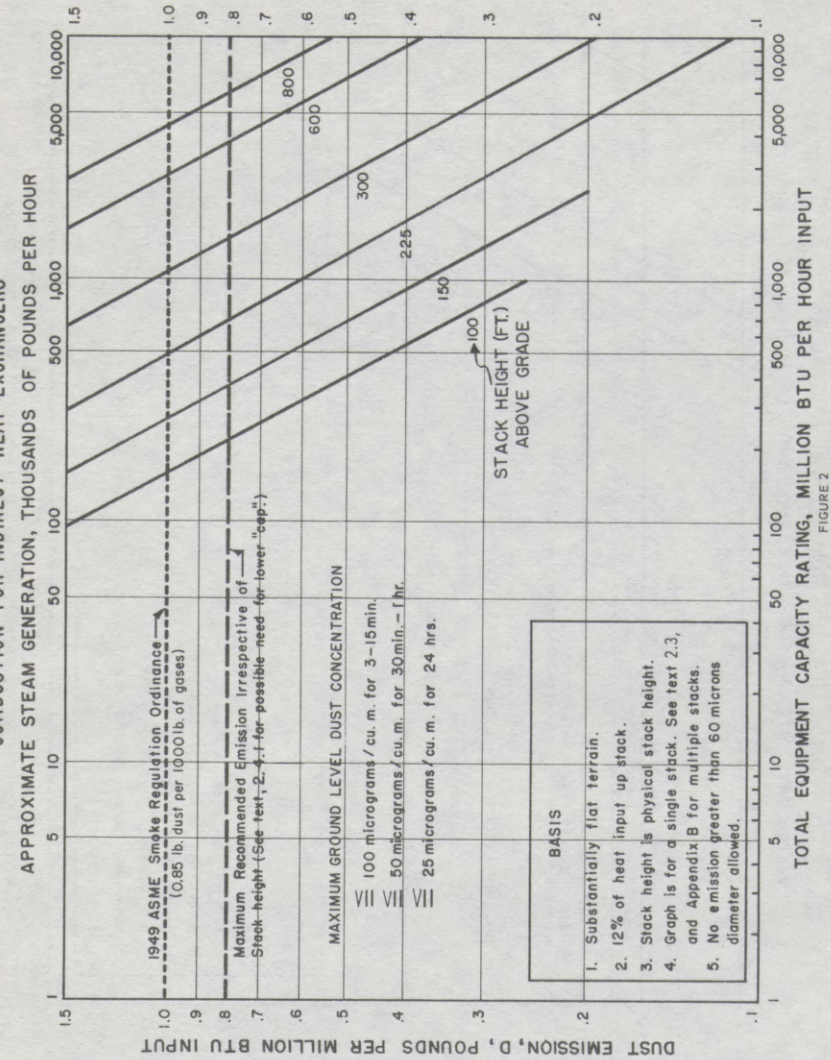

COMBUSTION FOR INDIRECT HEAT EXCHANGERS
APPROXIMATE STEAM GENERATION, THOUSANDS OF POUNDS PER HOUR
1949 ASME Smoke Regulation Ordinance
(0.85 lb. dust per 1,000 lb. of gases)
Maximum Recommended Emission Irrespective of
Stack height (See text, 2, 4, 1 for possible need for lower "cap".)
MAXIMUM GROUND LEVEL DUST CONCENTRATION
100 micrograms / cu. m. for 3-15 min.
50 micrograms / cu. m. for 30 min.-1 hr.
25 micrograms / cu. m. for 24 hrs.
STACK HEIGHT (FT.) ABOVE GRADE
100
150
225
300
600
800
BASIS
1. Substantially flat terrain.
2. 12% of heat input up stack.
3. Stack height is physical stack height.
4. Graph is for a single stack. See text 2.3, and Appendix B for multiple stacks.
5. No emission greater than 60 microns diameter allowed.
DUST EMISSION, D, POUNDS PER MILLION BTU INPUT
TOTAL EQUIPMENT CAPACITY RATING, MILLION BTU PER HOUR INPUT

FIGURE 2

mass rate of dust emission, stack dimensions, particle size of the dust, and atmospheric conditions. Large particles have a relatively high free-falling speed and, thereby, if not collected, can contribute to excessive dust fall. This effect for these large particles is especially pronounced in atmospheric temperature inversions. There should be no emission of particles larger than 60 microns (0.006 cm) diameter. This restriction will be met, in general, with a maximum dust emission from any stack as shown in Figs. 1 and 2.

4. STACK GAS CONCENTRATION

The previous considerations on dispersion have been based, among other parameters, on the mass rate of discharge (lb dust/hr $= D \times Q_H \times 10^{-6}$). The concentration of dust in the stack, lb/million Btu input, D, has, by itself, no direct influence on ambient air quality. Therefore, the concentration of pollutants in stacks should not be used as the single criterion of needed control to produce the desired or required ambient air quality. All the parameters, as defined in both Figs. 1 and 2 and Appendix A, must be used in these considerations.

5. OPACITY

Determination of smoke density by comparing the apparent density of smoke as it issues from a stack with a Ringelmann chart located 50 ft from the observer has become common practice in the United States. This Ringelmann concept is really applicable only to smoke, small particles of carbon that result from imperfect combustion. (Soot is agglomerated smoke.) The appearance of a smoke column depends primarily on the brightness of the sky, the true density of the smoke, and thickness of the smoke column. Therefore, as an example, smoke that has a Ringelmann number of 1 when discharged from a 4 ft diameter stack will have a much darker appearance when it is discharged from a 15 ft diameter stack. The Ringelmann number should be restricted to the use for which it was originally intended, i.e., smoke, with consideration of the factors that influence it. In general, Ringelmann readings should not apply to emissions whose density (appearance) is essentially due to water and/or whose rate of particulate emission meets regulations applying to particulate emission. Ringelmann number has no direct relationship to dust emission (lb/million Btu input), or to ambient air quality at the ground, as expressed by the suspended dust concentration. Therefore, Ringelmann number should not be used as prima facie evidence of nonstandard operation in relation to dust emission and ambient air quality as indicated by Figs. 1 and 2.

6. CONVERSION FACTORS

Those who are involved in air pollution control work are often beset with the problem of diverse units. A list of some conversion factors is given in Appendix C to aid in easy change from one set of units to another.

COMBUSTION FOR INDIRECT HEAT EXCHANGERS

NOMENCLATURE

a = fraction to make allowance for less than theoretical plume rise, dimensionless (a = 0.67, for example, for 67 per cent of theoretical rise)

A = constant in Lucas' plume rise equation, dimensionless

C_o = ground-level concentration, weight/unit volume

$C_{o_{max}}$ = maximum ground-level concentration with respect to distance, weight/unit volume

$C_{o_{max}^2}$ = maximum ground-level concentration with respect to distance and at the "critical" wind speed, weight unit volume

D = dust emission, lb dust/million Btu input

e = base (2.718) of natural system of logarithms

h_s = stack height, ft

H_e = "effective" stack height, ft ($H_e = h_s + \Delta h$)

Δh = plume rise, ft

n = number of stacks

p = vertical diffusion coefficient, dimensionless

q = horizontal diffusion coefficient, dimensionless

Q = dust emission rate, lb/sec

Q_H = total equipment capacity rating, heat input, Btu/hr

Q_{mw} = heat emission from stack, megawatts

u = wind speed, fps

u_c = "critical" wind speed, fps

x = downwind distance, ft

∂ = symbol for partial differential

APPENDIX A

1. Bosanquet-Pearson [1] Dispersion Equation

Beneath the axis of a plume

$$C_o = \frac{Q x e^{-H_e/px}}{\sqrt{2\pi}\, pqux^2} \tag{1}$$

By maximizing (1) with respect to downwind distance, x

$$C_{o_{max}} = \frac{0.215\, Q\, p/q}{u\, H_e^{\,2}} \tag{2}$$

Lucas' [6] plume rise formula is

$$\Delta h = \frac{A a Q_{mw}^{\,0.25}}{u} \tag{3}$$

Q_{mw} is the heat emission up the stack in megawatts (one megawatt = 3.42×10^6 Btu/hr). a is a factor, less than unity, to compensate for plume rise less than theoretical.

A is a constant, thought by Lucas and his coworkers to be about 5000 for a neutral atmosphere. Therefore, with $A = 5000$, Q_H (heat input) in Btu/hr, and assuming 12 per cent of this heat input goes up the chimney

$$\Delta h = \frac{68a\, Q_H^{\,0.25}}{u} \tag{4}$$

$C_{o_{max}}$ is greatest in relation to wind speed when $\frac{\partial C_{o_{max}}}{\partial u} = 0$. Therefore,

$$u_c = -\frac{H_e}{2\frac{\partial H_e}{\partial u}} \tag{5}$$

$$H_e = h_s + \Delta h \tag{6}$$

For a given stack height

$$\frac{\partial H_e}{\partial u} = \frac{\partial(\Delta h)}{\partial u} = -\frac{68a\, Q_h^{\,0.25}}{u^2} \tag{7}$$

Thus,

$$u_c = \frac{68a\, Q_H^{\,0.25}}{h_s} \tag{8}$$

and, therefore, at u_c

$$\Delta h = h_s \tag{9}$$

$$H_e = 2\, h_s \tag{10}$$

and

$$C_{o_{max}^2} = \frac{0.215\, Q\, p/q}{4 \times 68a\, Q_H^{\,0.25} h_s} \tag{11}$$

Taking $p/q = 0.63$ for a neutral or unstable atmosphere,

$$C_{o_{max}^2} = \frac{5.0\, Q \times 10^{-4}}{a\, Q_H^{\,0.25}\, h_s} \tag{12}$$

Since,

$$Q = \frac{D\, Q_H \times 10^{-6}}{3600} \tag{13}$$

$$C_{o_{max}^2} = \frac{1.4\, D\, Q_H^{\,0.75} \times 10^{-13}}{a\, h_s} \tag{14}$$

With the English system of units $C_{o_{max}^2}$ comes out in lb/cu ft. Multiply this times 15.9×10^9 to obtain the more conventional units of concentration of suspended dust in micrograms/cu m.

Thus,

$$C_{o_{max}^2} = \frac{2.22\, D\, Q_H^{\,0.75} \times 10^{-3}}{a\, h_s} \text{ micrograms/cu m} \tag{15}$$

where D, Q_H, and h_s are in the English system of units as defined in Nomenclature.

Concentration in the Bosanquet-Pearson equation (1) and succeeding ones is for a time duration of about 30 minutes. Concentrations for a shorter duration of 3 to 15 minutes will be approximately twice the concentration for 30 minutes. Figs. 1 and 2 were constructed, therefore, for maximum suspended dust concentration of about 200 and 100 micrograms/cu m, respectively, for a period of 3 to 15 minutes.

2. Pasquill

Based on Pasquill's work, Hilsmeier and Gifford [4] have prepared graphs for estimating atmospheric dispersion. Maximum concentrations under conditions of unstable atmospheric temperature stratification are, in general, higher than those under stable conditions.

Fig. 3 is a plot of $\frac{D\, Q_H}{C_{o_{max}}\, u}$ vs height of emission, H_e, for these unstable conditions. The following units are employed in the construction and use of Fig. 3:

COMBUSTION FOR INDIRECT HEAT EXCHANGERS

D = dust emission, lb dust/million Btu input

Q_H = heat input, Btu/hr

$C_{o_{max}}$ = maximum suspended dust concentration at the ground beneath the axis of the plume for periods of 3-15 minutes, micrograms/cu m

u = wind speed, ft/sec

H_e = effective height of emission, stack height above grade plus plume rise, ft

The maximum concentration, $C_{o_{max}2}$, from Fig. 3 must be determined by a trial-and-error procedure. This is done by assuming a wind speed, u, calculating plume rise, Δh, from equation (4) in this case, and then, determining $D\ Q_H/C_{o_{max}}\ u$ from Fig. 3. For given D and Q_H, $C_{o_{max}}$ can be calculated for the assumed u. Several trials with different wind speeds may be necessary to determine the maximum value of $C_{o_{max}}$.

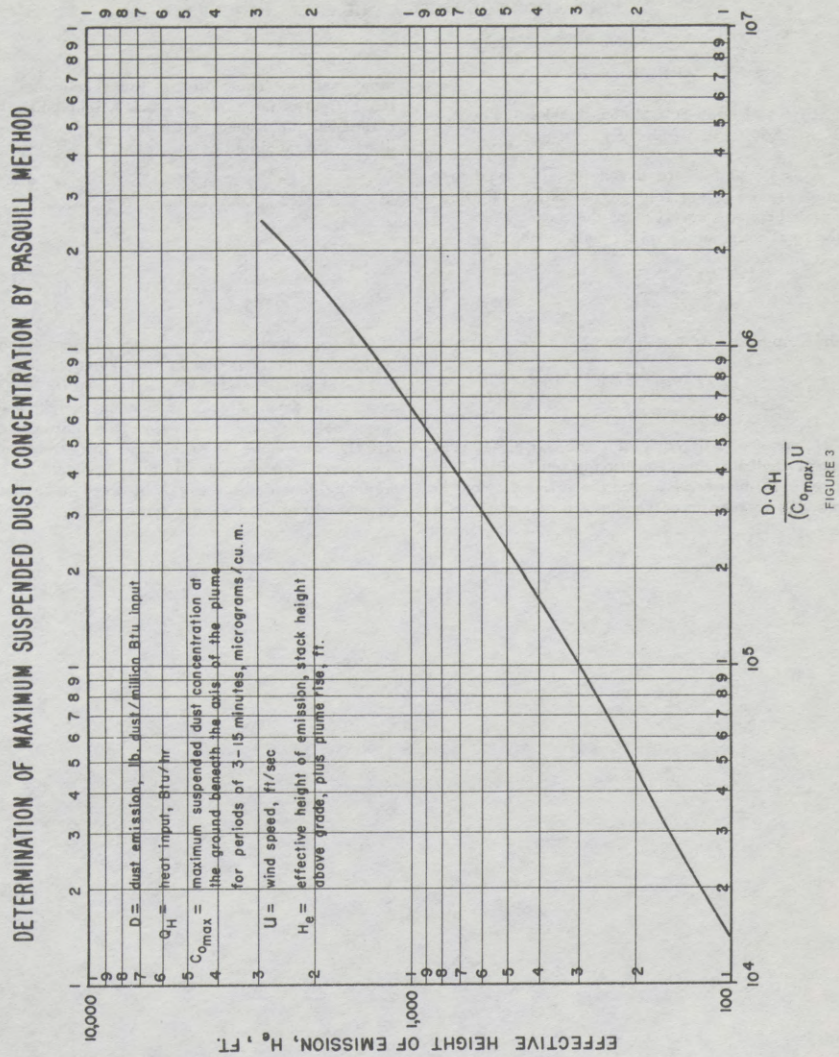

DETERMINATION OF MAXIMUM SUSPENDED DUST CONCENTRATION BY PASQUILL METHOD
D = dust emission, lb. dust/million Btu input
Q_H = heat input, Btu/hr
$C_{o_{max}}$ = maximum suspended dust concentration at the ground beneath the axis of the plume for periods of 3-15 minutes, micrograms/cu. m.
U = wind speed, ft/sec
H_e = effective height of emission, stack height above grade, plus plume rise, ft.
EFFECTIVE HEIGHT OF EMISSION, H_e, FT.
$\frac{D \cdot Q_H}{(C_{o_{max}})U}$

FIGURE 3

APPENDIX B

Effect of Load Split Among Stacks of Equal Height

Figs. 1 and 2 are based on all powerhouse stack gases going through one stack. If, however, there are n stacks of the same height and the total emission is split evenly among them

$$\Delta h = \frac{68\, a\, (Q_H/n)^{0.25}}{u} \qquad (1)$$

From Appendix A

$$C_{o_{max}}{}^2 = \frac{2.22\, D\, Q_H{}^{0.75}\, n^{0.25} \times 10^{-3}}{a\, h_s} \text{ micrograms/cu m} \qquad (2)$$

Expressed differently, for the same maximum suspended dust concentration given in Fig. 1 or Fig. 2, D (dust emission) in those figures must be reduced to take into account use of more than a single stack. Therefore, D (dust emission) in those figures for a given stack height and *total* plant heat input must be divided by $n^{0.25}$. Values of $n^{0.25}$ are tabulated below.

Number of Stacks *(n)*	$n^{0.25}$
1	1.0
2	1.19
3	1.32
4	1.41
5	1.50

The consideration in the foregoing paragraphs apply when the emission is split evenly among n stacks of equal height. With a load split, an uneven split among stacks of unequal height may sometimes occur. This case may not be as strictly amenable to the objective treatment considered previously in this Standard. The previous considerations can be used as a constructive base for decision, however.

ASME STANDARD – GUIDE FOR CONTROL OF DUST EMISSION

APPENDIX C

Conversion Factors for Air Pollution Control Engineers

Multiply	By	To Get
Btu/hr input	10^{-7}	megawatts of steam-generated electricity (approx.)
stnd cu ft/sec	mol wt × 9.3	pounds of gas/hr
stnd cu ft/min	mol wt × 0.155	pounds of gas/hr
grams/sq m	2.85	short tons/sq mi
grams/sq m/day	86.5	short tons/sq mi/mo
grains/stnd cu ft	1.89	pounds/1000 lb gas*
grains/stnd cu ft	2300	milligrams/stnd cu m
grains/stnd cu ft	2.30	grams/stnd cu m
grains/stnd cu ft (adjusted to 50% excess air)	2.20	pounds/10^6 Btu input
grams/stnd cu m	0.435	grains/stnd cu ft
grams of gas/stnd cu m	24.2×10^3/mol wt	ppm by vol
megawatts of steam-generated electricity	10^7	Btu/hr input (approx.)
micrograms of gas/stnd cu m	0.0242/mol wt	ppm by vol
milligrams of gas/stnd cu m	24.2/mol wt	ppm by vol
milligrams/stnd cu m	4.35×10^{-4}	grains/stnd cu ft
ppm by vol	mol wt × 41.3×10^{-6}	grams of gas/stnd cu m
ppm by vol	mol wt × 0.0413	milligrams of gas/stnd cu m
ppm by vol	mol wt × 41.3	micrograms of gas/stnd cu m
ppm by vol	10^{-4}	percent by vol
percent by vol	10^4	ppm by vol
pounds of gas/hr	6.48/mol wt	stnd cu ft/min
pounds of gas/hr	0.108/mol wt	stnd cu ft/sec
pounds/1000 lb gas*	0.53	grains/stnd cu ft

77-515 O-67-pt. 4—14

COMBUSTION FOR INDIRECT HEAT EXCHANGERS

APPENDIX C

Conversion Factors for Air Pollution Control Engineers (Cont.)

Multiply	By	To Get
pounds/1000 lb gas* (adjusted to 50% excess air)	1.18	pounds/10^6 Btu input
pounds/10^6 Btu input	0.45	grains/stnd cu ft (adjusted to 50% excess air)
pounds/10^6 Btu input	0.85	pounds/1000 lb gas* (adjusted to 50% excess air)
short tons/sq mi	0.35	grams/sq m
short tons/sq mi/mo	0.0116	grams/sq m/day

*mol wt = 29

m = meter
mol wt = molecular weight
stnd = standard at 70 F and atmospheric pressure

REFERENCES

[1] Bosanquet, C. H., and Pearson, J. L., "The Spread of Smoke and Gases from Chimneys," *Trans. Faraday Soc.*, Vol. 32, 1936, p. 1249-1264.

[2] Pasquill, F., "The Estimation of the Dispersion of Windborne Material," *Meteorological Magazine*, Vol. 90, 1961, p. 33-49.

[3] Pasquill, F., "Atmospheric Diffusion," D. Van Nostrand Co., Ltd., London, 1962.

[4] Hilsmeier, W. F., and Gifford, F. A., Jr., "Graphs for Estimating Atmospheric Dispersion," USAEC Report ORO-545, 10 pp., Oak Ridge National Lab., 1962.

[5] Moses, H., Strom, G. H., and Carson, J. E., "Effects of Meteorological and Engineering Factors on Stack Plume Rise," *Nuclear Safety*, Vol. 6, 1964, p. 1-19.

[6] Lucas, D. H., Moore, D. J., and Spurr, G., "The Rise of Hot Plumes from Chimneys," *Intern. J. Air Wat. Poll.*, Vol. 7, 1963, p. 473-500.

Senator MUSKIE. Let me give you an illustration of it; at least, I think it was an illustration.

Yesterday, a witness for the steel industry said that control of 95 percent of the particulates that are emitted from steel plants is possible at substantially less cost than control of 98 or 99 percent, so that as fast as they build new plants they build in 95-percent control. They build in the 99-percent control even though the technology is available only when they are satisfied that the ambient air quality is sufficiently poor that the addition of that must be made.

Now, that suggests to me that the 95 percent might be considered a minimal standard to be applied wherever such plants are located and that the 99 percent ought to be applied only in critical situations or in situations which might become critical projecting present conditions.

Now, is that a distinction that you think is valid, sound?

Mr. GARVEY. I think your point is a very valid one. You state the same approach I had been advocating; it is the control of the ambient air quality, not of emissions.

If you have to have 99-percent control to arrive at some given goal, and goal, I believe, is defined as criteria or criterion as a basis for developing this goal, if you have to have 99 percent and 99 percent can be achieved, then we can do this.

If you have to have 95 percent, then why go to 99 percent?

Somebody has to pay for this and it is the person breathing the air so therefore we should set a goal for air quality.

Senator MUSKIE. The point I am making is this: He testified that most steel plants are located in communities of 50,000 or more and the Public Health Service has told us that a community of that size or larger has an air pollution problem today.

I then asked him whether or not it was the policy of the steel industry whenever it built a new plant to build in all of the technology that was available to control emissions wherever that plant was located, and he said "Yes." Then later he qualified it by making this distinction between 95-percent control and 99-percent control.

So, the net of his testimony was that wherever a plant was located they built in 95-percent control whether it was in a small community or a large on. Presumably this was independent of any positive finding as to the ambient air quality in the community.

In other words, 95-percent control was a minimum effort that they built into any new steel plant. So the concept has been suggested in these hearings that we ought to require of certain industries a minimum effort wherever a plant might be located, and this is the first practical illustration of what that might mean.

So, I simply ask you whether or not you had thought about this difference in terms of a minimum effort that ought to be required of industries which by their character will add to air pollution wherever they are located. Up to the last day or two, when we talked about national emission standards, we were not talking about a distinction between minimum and maximum effort, but now we appear to be.

I would like to get a little testimony on the record from industry people as well as from the public officials on whether this distinction is meaningful and what it would mean in terms of a particular industry.

So, if you are prepared to comment on it now or later, I would like to have such a distinction. I probably am going to have to leave before you get into it.

Mr. GARVEY. I would be glad to submit something for the record on this particular subject but since you do have to leave, I do want to point out that for some pollutants, it may be posible to set minimal standards, particulates are a good example.

To do this with other pollutants such as sulfur dioxide might not be so easy.

Consideration should be worked out so that the emission conforms with the ambient air quality and is tied in but not as a fixed standard. I think it is going to be extremely difficult to set a minimal standard to achieve a given ambient air quality when you don't even know what the ambient air quality in a particular area is, or what is required.

I would be glad to submit additional comment on this.

Senator MUSKIE. Before you do it, if you read carefully the question in the final form in which I have posed it, I would appreciate a response to it in that form.

I am sorry; I do have to leave, Senator Randolph.

(See letter of May 29, 1967, p. 2416.)

Senator RANDOLPH (presiding). Mr. Garvey, would you proceed, please.

Mr. GARVEY. Now, let's move on to a discussion of the control of the emissions themselves. Where do we now stand in regard to the development of methods for reducing the emission of sulfur oxides from high-sulfur, coal-burning power stations?

The research which is underway can best be understood if we divide it into the four general approaches which are being pursued. These include:

(1) Removal of sulfur from the fuel;

(2) The addition of some material to the flue-gas stream following combustion; a material which will convert the gaseous sulfur oxides into solid form, probably sulfate, so that they can be subsequently collected along with the ash;

(3) The installation of a chemical processing plant through which the flue gases can be passed and the sulfur oxides converted into a salable product such as sulfuric acid or elemental sulfur; and

(4) The conversion of the coal to gas at the powerplant before combustion and the provision for the removal of sulfur from this gas prior to combustion.

At the hearings which this committee held 2 years ago, Mr. Harry Perry of the Bureau of Mines and I both described the technical problems attendant to removing sulfur from bituminous coals. But I believe a brief review is in order.

Sulfur occurs in bituminous coal in varying amounts between 0.5 and 6 percent. The sulfur is in the coal in three forms:

(1) As a sulfate;

(2) As an organic sulfur compound; and

(3) In a dispersed particulate form, iron pyrite.

The sulfate form is so minor, usually less than one-tenth of 1 percent that it can be disregarded. The pyritic sulfur varies from 40 to 80 percent of the total sulfur in the coals, and the remainder is essentially an organic combination.

The organic sulfur cannot be removed from the coal except by chemical alteration of the coal structure. While such chemical alteration is possible, it does not appear feasible because we then would no longer have coal; we would have a modified hydrocarbon more nearly approaching a fuel oil.

I would like to insert here that there is one project being carried out by one of the coal companies which involves dissolving all of the coal and removing all of the ash and sulfur and then precipitating the coal as a solid again. This is one project that has hope for not only removing the pyritic sulfur but also the organic sulfur and having a product left that is not coal but it looks like it.

Senator RANDOLPH. Is that the project of one company or the Bituminous Coal Research Institute or is it a federally funded project?

Mr. GARVEY. This is one agency, and the Office of Coal Research. We have nothing to do with it.

Senator RANDOLPH. Thank you very much.

Mr. GARVEY. The pyritic form of sulfur, on the other hand, is theoretically removable since it is present in the coal as a discreet particle. When the coal is crushed, the particles of pyrite are separated from the coal body itself and then are removable.

However, in most bituminous coals, these pyrite particles are extremely small; therefore, crushing of the coal is necessary in order to enable separation and subsequent removal. Since it is not feasible to ship crushed coal by rail from the mine to a powerplant, any cleaning which is accomplished after pulverization must be done at the powerplant itself.

But we have a factor in our favor here, namely, in practically all of the modern powerplants the coal is pulverized to about the consistency of talcum powder before it is burned. This offers us an opportunity to incorporate the cleaning process between the pulverization step and the burning step at the powerplant, and it is in this direction that our research on sulfur removal from coal is presently being conducted.

Since I appeared before this committee 2 years ago and outlined the research we were carrying out in connection with pyrite removal at powerplants, our work has progressed from the laboratory stage to the pilot-plant stage. We are currently, in cooperation with 12 electric utility companies who are cosponsoring the investigation, installing a 5-ton-per-hour capacity pilot unit at an existing power station in central Pennsylvania.

The system consists of modified crushing equipment to permit liberation of a maximum amount of the pyrite from the coal, combined with the use of both air classification and wet washing processes whereby we will take advantage of the difference in weight between coal particles and pyrite particles to remove the pyrite from the fuel stream.

Our preliminary laboratory tests indicated to us that this system should be capable of reducing several central Pennsylvania coals which contain, in the raw state, about 4 percent sulfur to somewhat less than 2 percent in the coal as burned at the plant. Two percent sulfur in the fuel is not low enough for some Public Health Service people, but it is an improvement possible with current technology.

The pilot test work on this investigation will require about 2 years to complete and, if successful, it is contemplated that the developments

which result will be incorporated in several large power stations which are being erected in the central Pennsylvania area and which will utilize these particular coals. High stacks are also planned to disperse the remaining sulfur oxides.

As I mentioned earlier, cleaning processes of this type will not remove organic sulfur. However, the coals which will be used in the central Pennsylvania area are low in organic sulfur; out of the 4 percent total the organic sulfur comprises only about 0.6 percent.

Senator RANDOLPH. What county or counties are embraced in the central Pennsylvania area to which you refer?

Mr. GARVEY. I am sorry, sir; I am not familiar with the counties in Pennsylvania, but it is around the Johnstown, Pa., area in that neighborhood, where these three large mine-mouth power stations are being put in.

Senator RANDOLPH. For the record there should be documentation.

Mr. GARVEY. I will do that, sir.

Senator RANDOLPH. You will supply it for us?

Mr. GARVEY. Yes.

Senator RANDOLPH. Thank you.

(Subsequently Mr. Garvey submitted the following information:)

The Pennsylvania counties affected are Indiana and Cambria.

Mr. GARVEY. Not all bituminous coals have such a low organic sulfur content and, therefore, we do not believe that all coal will be as cleanable as those of central Pennsylvania. However, we are hopeful that a number of coals will lend themselves to reduction in pyrite content through the utilization of this process. We are hopeful that this will enable sufficient reduction in stack emission that the contribution of a particular plant to ambient air quality will be tolerable.

To determine the extent to which our in-plant fine coal cleaning process will be applicable to the various coals which are consumed for power generation, we, in cooperation with the Taft Research Center of the Public Health Service, are carrying out an extensive coal sampling, analysis, and coal cleanability study.

This investigation, which is being conducted concurrently with our research on the development of better processes for removing additional pyritic sulfur from coal, will enable us to utilize the results of our pyrite removal research to the fullest extent possible.

So much for sulfur removal.

The second of the four approaches for reduction of sulfur oxide emissions involves the injection of some chemical material into the flue gas stream to convert the uncollectable sulfur oxide gases into collectable sulfate particulates. In other words, we are going to change this noxious gas into a solid so we can collect it.

The coal industry research laboratories are conducting bench-scale laboratory experiments on this approach. Other organizations, both in the United States and abroad, are also carrying out investigations, and the results of one of these will be preported to you later in these hearings by Mr. Jonakin; therefore, I will not go into specific detail.

However, the so-called additive approach is extremely attractive because of its relative simplicity and possible low cost. To be usable as an injection additive, the chemical must be low in cost, relatively

readily available on a wide geographic basis, and must react rapidly with the flue gases.

Limestones and dolomites appear to be the most usable chemical additives at this time and most of the research being conducted involves their use. Our investigations indicate that reactivity varies considerably with the many different types of limestones and dolomites which are available, and that a maximum of about 40 percent of the sulfur oxides in the flue gases can be converted to the solid form and removed with the fly ash collection system.

This 40 percent collection effectiveness of the sulfur oxides may seem at first to be disappointingly low, but reduction of the emission quantity by this amount, when combined with proper flue gas dispersal, can effect a material improvement in ambient air quality.

In addition, if the powerplant is using a coal from which a major portion of the pyritic sulfur can be removed by the inplant coal-cleaning process I described earlier, and if the flue gases resulting from this clean coal are further treated by means of an additive, a substantial reduction in SO_2 emission will result.

And if, as you will hear about later, the dry injection of a chemical additive is followed not by a dry ash-collection system, but by a wet scrubbing system, practically all of the surfur oxides can be eliminated.

Where do we stand on the development of chemical additives and their use in various combinations with other processes?

In our laboratories we are studying the chemical reactivity of over 50 different limestones and dolomites. This work is being coordinated with that of the Taft Research Center of the Public Health Service which is carrying out related studies in-house at its laboratories and is sponsoring, under contract with other organizations, studies of the physical characteristics of the limestones and dolomites.

The results of these investigations will enable selection of the most effective materials, and will optimize the selection of methods for injection into the flue-gas stream. Most of the laboratory bench-scale investigations will be completed this year and small-scale pilot investigations started. We are rapidly approaching the stage of research with these injection materials where full-scale powerplant tests will be required to demonstrate the feasibility of this approach and its several corollary approaches.

The third of the four approaches to reduction of sulfur oxide emissions involves the processing of the flue gases through a chemical absorption or adsorption device. This chemical treatment of the flue gases differs from the additive approach which I described earlier in two ways:

(1) A potentially salable chemical, either elemental sulfur or sulfuric acid, is produced rather than a waste product which is not salable; and

(2) The chemical conversion of the sulfur oxides takes place in a separate chemical plant rather than in the flue-gas passages of the boiler plant itself.

The two most promising processes at the present time are the alkalized alumina recovery system being researched by the U.S. Bureau of Mines, and the catalytic gas-phase oxidation process being researched by Monsanto Chemical Co. I understand that both of these processes

will be covered by other witnesses today; therefore, I will not comment on them further.

However, I would like to bring to the attention of this committee the fact that in Germany another absorption process is being researched, and in Japan a process very similar to the catalytic oxidation process is being investigated—to be covered by Mr. Stites—this process differing only in that, instead of sulfuric acid, ammonium sulfate, a fertilizer, is produced. Both of these processes are in the large-scale pilot stage of development, indicating that progress is being made in the development of the art of chemically absorbing sulfur oxides from the flue gases.

The fourth approach to control of emissions from coal-burning powerplants involves a drastic change in the design of the plant which converts the heat energy of coal into electricity. In the conventional plant of today the coal is burned directly to provide heat which, in turn, is used to convert water to steam and the steam is then used to drive generators which produce electricity.

Another concept currently under investigation, and I want to hasten to add that this approach is in the early stages of investigation, involves the conversion of the coal into gas before combustion, the cleaning of the gas produced to remove all pollutants, the combustion of the gas and the use of the hot products resulting for the driving of gas turbines to produce electricity.

This concept will not only eliminate air pollution from the coal-fired plant; it will, in addition, materially reduce thermal water pollution, and if the economic evaluations which we have made in cooperation with the Bureau of Mines and a leading powerplant manufacturer are accurate, it will enable a substantial reduction in the cost of producing electricity from coal. We may even be able to produce electricity for less cost than proponents of nuclear power think they can.

These are the four basic approaches being pursued today in the effort to find a means for control of sulfur oxide emission. In this review of the state of the art of sulfur oxide emission control processes, there has been time to mention only a few of the projects underway. I have for the most part covered only those which are nearing the commercial stage. Other witnesses who will follow me will elaborate on some of these projects.

But there are many other projects in the early laboratory stages, including the use of phosphate rock as absorbent, the use of hot salts for scrubbing of gases, high speed centrifuging to mechanically separate sulfur oxides from other flue gases and others.

I believe substantial research progress has been made in all approaches to the control of sulfur oxide deterioration of ambient air quality. Many organizations, Government and industrial, in the United States and abroad, are diligently pursuing this research. I personally know of research work being carried out by more than 20 such organizations.

We are confident that this research activity will eventually result in the development of a practical process for complete control of sulfur oxides. However, as I pointed out in introducing my statement, the complete answer has not yet been demonstrated on a commercial scale.

The research on many approaches is now leaving the laboratory, or

test tube stage, and entering the pilot and demonstration plant stages. At this point the research starts to become very expensive.

One pilot plant, equivalent to 25 megawatts of electric generation, may very well require the expenditure of several millions of dollars and, on a completely new approach, a full-scale demonstration unit may cost $10 to $20 million.

However, to produce a commercial process such plants must be constructed and operated. In this manner only can we obtain true cost and other operating data, and answer such questions as—

(1) What will be the effect of sulfur reduction in the coal on fly ash collection;

(2) Will additives affect the ash melting temperature and cause boiler deposits;

(3) Will wet scrubbing of flue gases so reduce the buoyancy of the gases as to cause dispersal problems;

(4) Will there be disposal problems with the sludge resulting from wet scrubbing—and many other questions which must be answered.

Recognizing the need for expensive plants to find the answers to such questions we endorse the sections of S. 780 and the amendments which call for increased research expenditures.

In closing this statement, I want to call the committee's attention to the fact that while the coal industry has often been in disagreement with officials of the Public Health Service on criteria, standards, and enforcement legislation, there exists one area in which we have been working together in complete harmony; namely, research.

In my statement, I made several references to our cooperative investigations with the Taft Research Center of Public Health Service, located in Cincinnati, Ohio. Industry engineers and scientists and those of this public health service research group, recognizing the need for a coordinated effort, have combined their capabilities in a most productive manner. We are hopeful that such a joint attack by Government and industry can be extended to include all aspects of the air pollution problem.

A coordinated effort by industry and Government involving a realistic approach to the establishment of tolerable or needed ambient air quality goals and the development of practical emission control methods will enable continued good health of both the public and the industrial segment of our country which the public also needs.

Thank you.

Senator RANDOLPH. Thank you, Mr. Garvey.

I know, of course, of your work in Bituminous Coal Research, Inc.

How long have you been engaged, Mr. Garvey, in this specialized field which qualifies you to discuss these matters with the subcommittee as an expert?

Mr. GARVEY. Directly connected with sulfur dioxides, our research in the development control processes goes back over 10 years. It goes back far beyond that when we consider other pollutants such as particulates in which the coal industry has been very active for at least 25 years.

Senator RANDOLPH. The reason I ask this question, Mr. Garvey, is that we, the members of the subcommittee, wish to have the benefit of your judgment as to when a technically feasible process for removing sulfur from coal or sulfur dioxide from gases would be available?

Mr. GARVEY. Well, I was invited to testify at the New York City air pollution hearings which were held 2 years ago and this same question was asked. At that time, I expressed the opinion that a minimum of 5 years would be required based on the state of the art at that time.

I still feel that this is a minimum timetable and that the state of the art, as we see it today, considerably advanced beyond that of what it was 2 years ago, will require another 3 years before full-scale recovery process plants are available on a commercial basis. I say this is a minimum timetable and to achieve it I am assuming that large-scale demonstration plants will be started in the near future.

I think we must recognize that by the term, "near future," I mean "now" because the construction of such plants requires a year to 18 months, and we have to have at least a year of testing and modification after that. So, I would say that another 3 years from now is a minimum.

Senator RANDOLPH. You have informed us in your statement, Mr. Garvey, of the technical problems that must be answered and these can be answered generally, if not totally, through what you call large-scale demonstration plants; is that correct?

Mr. GARVEY. That is correct.

Senator RANDOLPH. I think the subcommittee would be helped if you could go beyond what you have said and particularize in this field.

Mr. GARVEY. The point I was trying to make is that there are many things that we just cannot learn in the laboratory on the usability of a process. There are many questions which cannot be answered.

Maybe I can take some specific examples as the best way to explain this to the committee. For instance, let us assume that we conclude from our research on injection of additives such as limestone and dolomite that this is a logical course to pursue. We know from the work that has already been done that the use of such additives will approximately double the ash load on the dust collectors at a given plant.

Now, because most plants are designed for a given ash loading and the specific chemical composition of the material to be collected, it cannot be determined without the operation of a full-scale plant whether the added dust loading will reduce the particulate collection efficiency.

For example, efficiency may have been 99 percent but by this overloading it may go down to 95 percent. This cannot be resolved without large-scale plant tests.

Another question is related to these materials being injected into the boiler gas stream. As you know, the temperatures on a power boiler exceed 2,500°. This boiler, a large, expensive unit, was designed specifically to use a rather narrow range of coals. By this, I mean the coal ash characteristics were within given specifications.

Now, if the material injected, say, the dolomite or limestone, which are actually fluxes, affect the characteristics of the ash and they reduce the ash melting temperature then we get melting of the ash in the boiler. We will obtain buildup of deposits on the boiler walls and we may get some chemical corrosion in the boiler itself.

Questions such as these cannot be answered in the laboratory and they must be answered before we will know how effective a process is.

Senator RANDOLPH. There is a process under investigation by your organization, we understand, Mr. Garvey, to make pipeline gas from coal; is that true?

Mr. GARVEY. Yes, sir.

Senator RANDOLPH. If this work is successful, could this gas be used in powerplants and thus eliminate pollution, perhaps in a very substantial degree?

Mr. GARVEY. This is entirely possible.

Our organization is only one of several working with the Office of Coal Research and carrying out research to make a pipeline gas out of coal. By pipeline gas, I mean a gas that is exactly the same as natural gas.

We think that we can produce gas from bituminous coal which will have the characteristic of natural gas and at a price competitive with natural gas costs as they are in the coal producing areas.

What we are shooting at and what we think we can do is in the order of 50 cents per 1,000 cubic feet of gas and this is a very realistic price. It is near the price which the distributing companies are paying the pipeline companies for natural gas in and around the coal producing areas.

However, it does not seem likely to us that this gas would displace coal at powerplants. We should bear in mind that the average cost of coal to a power station is something in the order of 24 cents per million B.t.u. This is the cost delivered to a powerplant.

Now, if the same coal were converted into gas and the gas shipped from the coalfields to the power station, we would estimate that the cost to the power station would be somewhere around $1 per million B.t.u.; in other words, four times what they are paying per million B.t.u.

In our work, what we are doing in the pipeline gas research, we feel that we can make a gas which will compete for domestic heating and small industrial purposes but it is extremely doubtful that we can compete with the low cost of coal being delivered to power stations today.

Now, in my statement, I referred to the possibilities of a gasification project, gasification research, not only to eliminate pollution but also to reduce the cost of making electricity from coal.

I want to make sure I eliminate any possible confusion and I want the committee to understand that while the use of pipeline gas from coal does not appear to be an attractive possibility, the in-plant gasification process or making gas from the coal right at the powerplant, is a feasible approach to use; it will utilize much of the technology being developed as a result of the pipeline gas research but it is nevertheless an entirely different approach.

The gas produced will be much lower in quality than the pipeline gas but because it will be used on the site, it provides us with certain technological and economic gains.

Senator RANDOLPH. Mr. Garvey, I recall that during the 1940's, Senator O'Mahoney of Wyoming and I authored the Synthetic Liquid

Fuels Act. At that time, we were seeking to make gasoline from coal, especially aviation gasoline; also, to utilize oil shale in the same investigations.

The reason I mention this now is that, at that time, our primary consideration was not the cost factor but the submarine menace to the shipment of oil to this country. So we were intensely interested in the defense aspect and to assure a supply of oil or synthetic oil and gasoline in wartime.

The programs, the projects, the experiments carried forward during those years indicated that we could produce aviation fuel from coal and that we could even produce it from oil shale.

Yet, during that period our primary interest was not in lowering of the cost, although naturally that was a part of the state of the art and of the research itself.

Today, we are continuing, after a lapse of years, an effort to produce gasoline from coal and we are thinking now primarily of the cost factor, which was not the primary consideration in the 1940's during World War II.

So, in a sense we face that problem today, do we not? You have spoken of the two considerations: Can we do the job and what is the cost of doing the job? There is added the third factor: How long will it take to do the job?

Would you like to comment a little further because of what I have said?

I have referred to the past because I did want to indicate what had been done with Federal funds in cooperation between Government and industry back in the 1940's.

Mr. GARVEY. There are two factors which are different between now and what it was in the 1940's.

First of all, the cost of the natural liquids, and gases has increased.

Senator RANDOLPH. Yes, sir.

Mr. GARVEY. The price has gone up so we have brought closer together the cost of the natural product and the synthetic product. In addition, some technological advancements, particularly in the areas of operating reactors at high pressures, extremely high pressures, better catalysts, better combinations of hardware have resulted from the research which has been carried out by the gas industry and by the coal industry.

One of the leading cool companies has researched this for a number of years, and then more recently the Office of Coal Research has participated in the sponsorship of this work.

Where do we stand now?

Insofar as the liquid situation is concerned, I understand at the end of this month they are going to dedicate in West Virginia one of the first pilot plant operations to produce gasoline from coal and their expectations are that this will demonstrate the feasibility of this research approach—and this is another example of a demonstration plant. There are many questions that cannot be answered in the laboratory and it is necessary to build a plant of this size. But they expect to produce gasoline for 11, 12 cents a gallon which would be competitive.

As far as gasification is concerned, two projects sponsored by the Office of Coal Research are under consideration now for the erection

of large pilot demonstration plants. There are several other approaches which are just coming out of the laboratory; you might call it the test-tube stage; and these also will be ready and available.

It appears that, if the technology moves at the rate that it is moving now and it is amply funded, sometime in the early 1970's we will be able to design and erect a commercial plant to make gasoline out of coal. And sometime perhaps in the late 1970's, I would say, the gasification projects should be commercial. I am talking about pipeline gas.

Senator RANDOLPH. You are correct in indicating that the formal dedication of the liquid fuels plant in West Virginia will be the latter part of this month. I wish to commend my colleague from West Virginia, Senator Robert C. Byrd, for the effort that he has made in this regard, an effort which I made in an earlier period, in the 1940's, about which I have spoken here today when I joined Senator O'Mahoney in the sponsorship of the Synthetic Liquid Fuels Act.

I am glad, frankly, that the two Senators from West Virginia have been thinking in terms not just of coal but of the products that can come from coal which can benefit our economy and in part, perhaps, answer some of the air pollution problems we are considering here today.

You will recall, too, Mr. Garvey, that back in the 1940's we were attempting in Alabama, for instance, to find if we could develop a coal gasification program that would be successful. Do you remember the efforts in that area?

Mr. GARVEY. Yes.

Senator RANDOLPH. In both the liquid and gas studies we made some findings which were of value. I remember when I flew from Morgantown, W. Va., to Washington, through the rain on a Sunday evening in 1945 with Arthur Hyde, the West Virginia boy who was an excellent pilot. We flew in a Fairchild single-engine aircraft, the first and only plane in this country powered by gasoline which had been made from coal. That coal had been processed into synthetic gasoline at the Pittsburgh station of the Bureau of Mines.

I remember with some trepidation that flight across the mountains because it was the first time in this country that we had ever flown a plane with gasoline processed from West Virginia coal.

Mr. GARVEY. High sulfur coal.

Senator RANDOLPH. Yes.

I well remember we brought the barrel of gasoline down from Pittsburgh by truck and then we pumped it out of the barrel after having allowed the conventional gasoline to be drained from the tank. I felt somewhat ill at ease as I saw that so-called proven gas come out of tank and the other gas go in—but the flight was successful.

I am a strong believer in research and in pioneering in these fields. Even at the expense of having someone indicate that I might be overpersonalizing this part of the hearing, I would like to recall that there were persons who were working against difficulties in those hours of our history some 20 years ago. Today, we are challenged as we were then, but for different reasons.

Now the problem of air pollution is a very real problem against which we must make an all-out frontal attack. We must have realistic

and reasonable administration and legislation, not only to abate but to control air pollution, and, as chairman of this full committee, I am dedicated to that accomplishment.

I feel that my determination in this respect is shared by all of us in the building of a better country in which our people can live in health and security.

I thank my colleagues for indulging me this morning. Now, I have another question Mr. Garvey:

We know that your organization has been studying the problem of patents, including the acquisitions of patents by the Government. I have introduced amendment 181 which deals with this subject.

Would you comment on that, what your organization would feel?

Mr. GARVEY. I am not quite sure, Senator, that I understand your question on this particular subject; it is not one which I am informed on, not being in the legal profession.

Would you care to rephrase your question from the standpoint of an eliciting answer by an engineering research man?

Senator RANDOLPH. I understand, and I will ask it of someone else but I think your organization would have a position on this matter.

Mr. GARVEY. I am sorry, sir. I cannot comment directly. I can get the comment for you and submit it for the record.

Senator RANDOLPH. Just at the moment, Mr. Garvey, could you have someone here comment on it? I would like to clarify it at this point.

Thank you, Mr. Dunn.

Mr. Dunn has appeared already before our subcommittee, and we are pleased to hear his comments on this subject.

Mr. STEPHEN F. DUNN (president, National Coal Association). Thank you.

Mr. Chairman and gentlemen, as I understand the question, it had to do with the position of our organization as to patents.

Senator RANDOLPH. Yes, sir. We are talking about research.

Mr. DUNN. Yes.

In that connection, of course, we have been working with the Office of Coal Research which does, as I understand it, require some dedication of patents to the public demand.

I would like very much, Mr. Chairman, to submit a statement for your committee after some consideration. We have not considered the subject of patents in the context of these hearings and the amendments which you have offered. I would like to present a more meaningful and knowledgeable answer to your question if I may for the record.

Senator RANDOLPH. That will be agreeable, Mr. Dunn.

Mr. Garvey, we feel this is a very important factor in the research program and we would want to have your organization's position on the subject. As I mentioned, amendment 181 relates to this subject, too.

Mr. DUNN. So far as Bituminous Coal Research is concerned, I can see absolutely no problems. Of course, in cooperation with Government on an expanded research program we would want to do whatever would seem proper under the leadership of this committee and the law in its final form.

Senator RANDOLPH. I think, Mr. Dunn, that will help us at this point.

(Subsequently the following information was submitted:)

NATIONAL COAL ASSOCIATION,
Washington, D.C., May 22, 1967.

Hon. EDMUND S. MUSKIE,
Chairman, Subcommittee on Air and Water Pollution, Committee on Public Works, New Senate Office Building, Washington, D.C.

DEAR SENATOR MUSKIE: At the May 16, 1967 hearing before your Subcommittee, Senator Randolph asked James R. Garvey to comment on the "matter of patents which can be acquired, would be acquired under Amendment 181 by the Federal Government for use in these programs of research" (Transcript, p. 1015). When Mr. Garvey referred the question to me, I stated that we would provide for the record a statement as to our position in this regard (Transcript, p. 1016).

Amendment No. 181 would authorize the Secretary of Health, Education, and Welfare to: "acquire secret processes, technical data, inventions, patent applications, patents, licenses, land and interests in land, plants and facilities, and other property or rights by purchase, license, lease or donation; * * *." (Sec. 104(c)(4).)

We are of the view that the foregoing provision is most desirable and should be included as part of the research amendments to the Clean Air Act. Government-sponsored research often necessitates the acquisition of privately-owned patents and Congress has recognized the desirability of specific authorization in this area in other legislative enactments. See, the example, Section 3(f) of the Saline Water Act and Section 6 of the Office of Coal Research Act.

Sincerely,

STEPHEN F. DUNN, *President.*

Senator RANDOLPH. Mr. Garvey, how much is being expended by the coal and power industries on sulfur research?

Mr. GARVEY. Senator, when I appeared before this committee 2 years ago, this same question was asked and at that time I pointed out that in the joint research program which the coal and electric utility industries were carrying out we spent about a million dollars in the previous 8 years on research directly to sulfur dioxide. This represented an effort of about $125,000 a year. Since that time, the effort has been greatly increased.

In early 1966, the coal industry and the utility industry, through the Electric Research Council—and I believe the head of this group is to testify before one of your hearings—joined in the establishment of a $4.3 million program, this money to be spent over a 5-year period. The effort was to be equally shared and was to be equally divided between health effects of sulfur dioxide and more methods on control of emissions.

This, of course, would also include removal of sulfur from coal.

The health effects research is being carried out by the Hazelton Laboratories of Falls Church, Va., and their rate of effort is now about $440,000 a year. The sulfur recovery work we are carrying out ourselves in our own laboratory and we are also spending at about this rate of effort.

Therefore, we can say that in the past 2 years the coal and electric utility industry have increased their expenditures almost sevenfold. Now, this is only work being carried out under that one specific program which involves our association activity. It does not include the work that is being conducted by individual coal companies and utility companies which I am sure would at least double that cost.

Today you will hear from two representatives of commercial companies which have spent their own funds and have worked in cooperation with specific utilities, and obviously some of their funds were

involved. I would say at the present time the rate of effort far exceeds $1 million a year by industry, including coal and electrical.

Senator RANDOLPH. Thank you, Mr. Garvey.

Senator Boggs.

Senator BOGGS. Mr. Chairman.

Let me say at the outset that I want to take this opportunity to congratulate the distinguished chairman, Senator Randolph of West Virginia, on making the comments he made just a while ago.

I have observed your personal interest over a number of years, and have been a great admirer of yours. I congratulate you on your vision, on your courage, and your constructive action in this field.

Senator RANDOLPH. Thank you, sir.

Senator BOGGS. We are all proud to serve with the chairman.

Mr. Garvey, I certainly have been impressed with your statement and I congratulate you on the progress you have made, and it certainly does give us all high hopes for the future as this research goes on.

Certainly, I am sure we all want to encourage industry as well as Government to work together in this important research field because there is so much we don't know and we have got to find these solutions as we attempt to control this air pollution.

The question in my mind is, and you have heard the questioning on the testimony during these hearings, much emphasis has been on research and properly so. As I say, we want to encourage it.

Now, I know technology like everything else is moving very fast today. I guess one of our problems at this time in writing whatever legislation may come out of these hearings is to make sure that we are doing all that we can do now, all that is technologically and economically feasible to do now, make as much progress as we can at this stage in the control of air pollution and all of its many faceted problems.

I was wondering if you would care to comment. You have done so well on research as to your own information or your own views: are we doing all that is technologically and economically feasible now in the main fields or the fields with which you are familiar to control this problem. Are we applying what we know now to the control problem?

Mr. GARVEY. Yes, sir; I believe we are. We can speak, for example, to the control of particulates. The utility industry has spend large sums, I believe I heard the number as three-quarters of a million dollars, on installing collectors. This is an accomplished technology which has been developed through research; it is being applied.

I know that the utility plants being constructed now have given serious consideration to elevated stack for control. This is not cheap; this adds to the cost of producing electricity. I believe that the industries themselves have expressed the intent to utilize every possible tool to control pollution research.

As was brought out by the witnesses at the hearing yesterday, the steel industry I think, they are installing dust collectors. They did however point out the need for a realistic approach. There is no point putting a 99-percent efficiency device in when a 95-percent will suffice because the cost curve goes up very rapidly as you try to get down to zero emission.

In other words, as you approach infinity you start getting more and more expensive. Therefore, it seems that legislation should be so couched, so prepared as to provide requirements for air quality—not emission control.

I am certain as an engineer—not an expert in the legislative field—that the best approach is to encourage cooperation between Public Health officials and industry in developing not standards but goals, criteria which will enable everybody to live together and work toward a realistic objective which has been defined. If the legislation can define this objective, this is very well and good. I don't think our clean air goals can be achieved by setting an overall standard to apply to every industry and every part of the country in every community. It just does not make sense to me.

There is much that still has to be learned in research and anything that encourages the conduct of research is certainly worthwhile.

Senator BOGGS. Thank you.

Senator RANDOLPH. Senator Baker.

Senator BAKER. Mr. Chairman.

This is a matter of such obvious interest to all of us in writing this legislation that I would be redundant if I tried to underscore and redefine the great concern that all of us on this committee have in preparing the proper form of language to accomplish these purposes.

I, too, want to commend the chairman of the full committee, now sitting as the chairman of this subcommittee, for his in-depth knowledge in this field and his dedication to realistic legislation to accomplish both the purposes of air pollution control and the purposes of industrial vitality, that of the coal industry in particular.

Mr. Garvey, I realize that there will be other witnesses to speak on these matters, to give us more technical and detailed analyses of various methods for the reduction of sulfur compounds from stack emissions and the like, but there is one item on page 18 of your statement which I wonder if you would elaborate on just a little bit. And that is the so-called fourth approach to the control of emissions from coal-burning powerplants; that is, the reduction of coal to gaseous form and the utilization of that gas to directly propel turbines, bypassing the steam step. Of course, you still have combustion.

Mr. GARVEY. That is right.

Senator BAKER. I wonder if we wouldn't still have combustion byproducts that would have to be contended with as pollutants.

Mr. GARVEY. Only to the extent that when you are burning natural gas—we would clean up the gas; yes.

Senator BAKER. I see.

After the coal was gasified, then there would be a reduction process to remove the heavier hydrocarbons?

Mr. GARVEY. Yes, and dust and everything else.

Senator BAKER. And to use the pressure of the gas that was produced by combustion to directly drive the turbine?

Mr. GARVEY. That is right. This has been done and it is taking off on the technology that we and others have developed in connection with making pipeline gas to accomplish a gasification that can be done in-plant, not to go all the way to pipeline gas but to stop at some intermediate point.

77-515 O—67—pt. 4——15

Senator BAKER. So, we would be using a gas turbine concept?

Mr. GARVEY. Yes. This would be done. One of the things that makes it feasible and makes it possible to us is that it would be done under high pressure.

Senator BAKER. That is the last point I was going to reach.

Once again, I will not burden you unduly with an elaboration of this technique, but would the combustion of these gases produce sufficient pressure for plant purposes or would you have to compress it?

Mr. GARVEY. Compress it. We are thinking 30 to 40 atmospheres right now.

Senator BAKER. Which would be a pretty expensive power requirement by itself.

Mr. GARVEY. Well, the overall concept has to be considered and in this concept the cost of compression is not a burden. We are looking ahead and I think everyone should do this. How are we going to be generating electricity from coal 5, 10 years hence?

Senator BAKER. That is why this fourth approach is so intriguing to me. If we can substantially reduce the cost of producing electricity or producing energy, of all the approaches you have opened up for us, that is the most fascinating for me.

Mr. GARVEY. We feel all the others are makeshift. We are trying to solve a problem which is an inherent part of the equipment and therefore does not lend itself to solution. A new approach is needed.

Senator BAKER. This would have to alter the desirable characteristics of coal as we now know it.

For instance, it would not make much difference what the sulfur content or ash content was if you are going to gasify it to begin with and depend on the vaporous byproducts to produce pressure gas to drive turbines; it would not make any difference whether it was 18 percent ash or 40 percent ash, would it?

Mr. GARVEY. No; only minor effect on the economics.

Senator BAKER. It would have a minor effect on the economics.

From that point of view, it would surely have a profound effect on the type of coals that were required. This technique might open up coal reserves which are not now economically desirable, high ash coals and high sulfur coals and the like; is that correct?

Mr. GARVEY. That is entirely possible.

Senator BAKER. How far along in the technology or design of this approach are we?

Mr. GARVEY. We are fascinated with it, too, and we are working with another organization that proposed a project to the Office of Coal Research. The Office of Coal Research appears to be interested in pursuing it.

We have also discussed this with the research center of the Public Health Service; as a matter of fact, I think one of their witnesses mentioned it in his testimony as being an approach that should be pursued.

We are at the stage now where we have made an economic evaluation of the feasibility and the economics of this and it looks good to us; we think it should be pursued, and we hope we can get off the ground with it.

Senator BAKER. Has anybody built a laboratory model of this?

Mr. GARVEY. No; no model. This is going to be big.

Senator BAKER. Of course it would be, and in order to test the economics of it, I suppose you would have to have a production-type kind of a plant.

I wonder if on a smaller scale the actual operation of this process has been demonstrated in the laboratory.

Mr. GARVEY. Well, I tried to indicate in my testimony this stage of the work is really being done as a part of the natural gas or the pipeline gasification work which is being carried out and this is a takeoff on that. We are using similar technology.

Senator BAKER. Midpoint between the solid fuels and gaseous fuels, someplace in between those two.

Mr. GARVEY. We think we are now ready to design a pretty good sized plant and this is the only way it can be done.

Senator BAKER. Let me ask you this concluding question.

Before I do, is there some other witness today to elaborate further on this technique?

Mr. GARVEY. No.

Senator BAKER. Is there material that you can supply for the record that might further elaborate?

Mr. GARVEY. Yes; I can submit a statement for the record.

Senator BAKER. Can we get that, Mr. Chairman?

Senator RANDOLPH. Yes.

(Subsequently, Mr. Garvey submitted the following information:)

THE COAL GASIFIER/GAS TURBINE METHOD OF ELECTRIC POWER GENERATION

It has long been recognized that power generation efficiency can be improved by combination of a Brayton Gas Cycle with Rankine Steam Cycle. Many combined gas-steam turbine plants have been built, but currently none burn coal, and no system for their operation on coal is ready for commercial operation.

Other methods of improving the efficiency of power generation using coal are under investigation; for example, Magneto-Hydro-Dynamics and Electro-Gas-Dynamics. These methods, however, are in a far less developed state than is gas turbine technology. Gas turbines should logically become a factor in coal fired power plants before either MHD or EGD. The very rapid advances in performance being made by gas turbines should also be recognized. When this factor is taken into account, the efficiency of a system employing an advanced gas turbine compares favorably with, for example, an MHD system, and the cost of applying gas turbine technology is likely to be a fraction of the cost of the MHD development which would be required.

The combined gas-steam turbine cycle is promising for air pollution abatement because the intended integration of a gas turbine with a coal gasification process provides an opportunity for sulfur removal by hydrogen sulfide absorption at low cost.

Thermal pollution is reduced by a central station combined gas-steam turbine power plant because at the higher efficiency less heat is rejected. River or water thermal pollution is reduced in a greater proportion because more heat is rejected direct to atmosphere and less to water.

The gas turbine when used for industrial power generation with use of exhaust heat in a process, offers the following favorable characteristics:

(*a*) A cycle thermodynamically similar and with efficiency comparable to a back pressure steam turbine, but able to develop up to four times as much power in relation to the process heat requirement as a back pressure steam turbine.

(*b*) Flexibility of power generation independent of the process steam requirements.

(*c*) A heat rate approaching one half that of central station power generation.

(*d*) Corresponding improved economics and better payout periods than conventional energy systems.

(*e*) Little or no air or thermal water pollution.

The gasifier/gas turbine approach offers the best chance for development of economic recovery of the sulfur compounds produced by combustion. Since the gas pass of a conventional power plant boiler is at atmospheric pressure, removal of the sulfur products from the stack gases requires either processing of large volumes at atmospheric pressure or requires the installation of costly compression equipment. Raising the gas pressure also reduces the thermal efficiency of the power plant by consuming power otherwise available for sale or use. These limitations have largely been responsible for unsatisfactory economics of the various processes proposed to clean up the stack gases of conventional power plants.

As an alternate to processes to remove the products of combustion of sulfur from the power plant effluent, it has been suggested that coal should be gasified and that the sulfur should be extracted as Hydrogen Sulfide (H_2S) from this gas followed by combustion of the desulfurized gas in the power plant. Several processes for H_2S removal are in commercial use but not in power plants. These processes are more economical when operated at high pressure.

The gas turbine incorporated in the proposed plant will perform much of the compression function required by the pressurized gasifier and will also improve the overall economics by an improvement in efficiency. Both the gasification and gas turbine economics will be improved by shared facilities.

The H_2S may be absorbed in dry iron oxide, or activated carbon, or in wet aqueous absorption processes. The use of activated carbon holds the attractive possibility that the required activated carbon could be prepared from coal in the plant and subsequently burned in the plant when spent. All of the proposed processes convert the H_2S into saleable sulfur or sulfuric acid. This factor might be very attractive to industries which use sulfur or sulfuric acid.

The overall economics of the coal gasifier/gas turbine method of power generation appear extremely favorable. Assuming an 800 megawatt power plant with an 80 percent operating factor, capital at 12.5 percent and coal at 20 cents per million Btu, it is estimated that electricity can be produced for 3.85 mills per kilowatt hour. And if the sulfur recovered from the proposed plant is sold at 25 dollars per ton, the electricity cost is reduced to 3.65 mills per kilowatt hour.

These costs are a substantial improvement over the 4.33 mills per kilowatt hour anticipated with nuclear plants of current design.

Senator BAKER. Mr. Garvey, you and your associates should give to the subcommittee all information pertinent to the proposal, documented as carefully as you can so as to help the subcommittee.

Mr. GARVEY. Yes, sir.

Senator RANDOLPH. Thank you.

Senator BAKER. Might it not be possible and desirable, Mr. Garvey, from an economic standpoint, to combine the processes here. Instead of using compression to raise the head pressure of these turbines gases, might we not, in fact, use other fuels like natural gas or pipeline gas manufactured from coal, high-quality low-sulfur coal, to superheat these gases and bypass compression?

Mr. GARVEY. It is an approach that could be considered.

Senator BAKER. I think it a most promising direction, Mr. Chairman. I look forward to hearing more of it.

Thank you, Mr. Garvey.

Senator RANDOLPH. Senator Cooper.

Senator COOPER. I have no questions.

Senator RANDOLPH. Mr. Garvey, you have mentioned that we may even be able to produce power through the gasifier/gas turbine method for less cost than that of nuclear power and you have underscored that word.

I have been contacting the President of the United States and all the people whom I could approach in the Congress and in the execu-

tive branch of the Government reminding them of the very, very considerable amounts of money spent by the Federal Government in nuclear power research. Now, I did not take the position that these moneys should not be appropriated and used, but I took occasion to compare these huge dollar sums for nuclear power research with the very limited funds that have been allocated to coal research.

I will place in the record figures which underscore my concern in this area—a concern that I think is shared by numerous colleagues, at least in part.

In one letter written last October I used this language:

> Certainly coal research must be placed on a parity basis with Federal research for nuclear power development which an official of the Atomic Energy Commission recently stated is now approximately $300 million a year.

I believe our most recent figures indicate that we are spending annually about $8 million of Federal funds on coal research through the Office of Coal Research, plus approximately $6 million through the Bureau of Mines.

I will place in the record, if there is no objection from my colleagues, certain correspondence and certain figures.

The reason I have chosen to add these comments to the record is that you have indicated that we may be able to do something in connection with the production of electricity with coal that, frankly, may not be feasible even dollarwise with nuclear power. Is that right, Mr. Garvey?

Mr. GARVEY. The approach we are taking, we believe, will develop means for producing electricity from coal which will be cheaper than the figures which the nuclear people expect they will achieve when these new nuclear plants are on the line.

I certainly want to comment on the disparity and funds being spent for nuclear power as against coal. I want to point out that we—and by "we," I mean the coal industry—and I think others should be extremely grateful to you, Senator, and your associates who have recognized that the needs for the energy of the future is going to require the use of every bit of fuel that we have available and that we should spend money, as you have encouraged the Office of Coal Research, for funding of these various programs. An ample share of our available funds should be spent on all fuels so that we can develop the technology not for a selected few but for all of them.

We feel that if the rate of effort and fund expenditure that have been devoted to nuclear had been, even in part devoted to the other fuels we would not be talking about dedicating a gasoline from a coal plant now; we would be talking about buying gasoline from it.

Senator RANDOLPH. Thank you, Mr. Garvey.

I appreciate your testimony. I think the members of the subcommittee are going to find it necessary, and I know they will find the time, to go into these matters very carefully in the subcommittee as we consider the writing, the refining, the markup of this legislation. We do not want to delay the legislation.

Senator Muskie, the chairman of our subcommittee, will not want to delay legislation. I will not want to delay the legislation. We need not delay it. We can move forward with reporting a measure.

It is my desire that we proceed, however, with a realistic and reasonable approach, yet with the definite determination to face up to the problem of air pollution and to eliminate it.

Thank you, Mr. Garvey.

Mr. GARVEY. Thank you, Senator.

Senator RANDOLPH. I will ask Senator Boggs to take the chair, if you will, at this time because I have other business in another committee with which I must share time and attention this morning. Before doing so, however, I submit the material for the record of this hearing to which I made earlier reference.

(The information referred to follows:)

SENATOR RANDOLPH DISCUSSES NEED FOR PARITY IN GOVERNMENT RESEARCH FINANCING OF NUCLEAR POWER INVESTIGATION ON THE ONE HAND AND COAL ON THE OTHER

In addressing the Senate on June 30, 1966, this Senator from West Virginia emphasized these observations:

I know that, as far as the coal industry is concerned, there is a complete acceptance of the fact that nuclear power is a real and pressing competitor of conventionally generated electricity.

I know, too, that Chairman Seaborg of the Atomic Energy Commission and others who are knowledgeable on the subject have repeatedly issued assurances that nuclear power does not really compete with coal, but is, in effect, a supplementary source of power. They say this is because the demand for electricity is growing at such a fast rate that—despite the introduction of vast amounts of nuclear power into the Nation's energy supply systems—coal will double in usage for generation of electricity by 1980.

But I must point out that we cannot ignore the fact that nuclear power is developing three times faster than the AEC forecast in projections as late as 1962. Further, the fact is that notwithstanding this upsurge in nuclear power under present technology and equipment available, the AEC is not retrenching in its multimillion-dollar research and development program to strengthen further the competitive position of nuclear power.

I emphasize the fact that our Government has not made any move for a redress in the startling imbalance which has long existed between research and development funds for nuclear power research and funds for other forms of energy research. The disparity continues to be very substantial.

In fiscal year 1967 appropriations, the Office of Coal Research was funded in accordance with budget requests of the President at approximately $8 million for its total research program, with approximately $5 million additional for the Bureau of Mines. Best estimates available indicate that upward to $300 million of Atomic Energy Commission budget items were available for nuclear power investigations.

The disparity may be somewhat less in fiscal 1968—but still much out of line, in my view—being approximately as follows:

For the Office of Coal Research, a budget request of $9.6 million and for the Bureau of Mines, $6.7 million, compared with approximately $259 million for nuclear power research and development in the AEC budget.

My comments on disparity of this magnitude in the Senate on June 30, 1966 continue to be my views, summarized as follows:

Coal research, of course, needs to be carried forward in a greater degree. Not that we feel that nuclear research is unimportant; we do feel that the Nation will have to look to nuclear power to provide a large share of the immense amount of energy which we will use. But we are also going to need the coal resources to generate that power.

Nuclear research is important, and it should be carried on by the AEC.

But to reach a stage in the development of nuclear technology where nuclear power will become the dominant energy source certainly should not mean that the Nation should be satisfied with anything less than the ultimate benefits from its plentiful natural resource, coal. We are in the atomic age, but we must remember the fact that this also is the age of coal—the real and dependable work horse of the energy field for many decades.

Our country will need all of its energy resources in the future.

With the huge population increases, with our metropolitan centers pushing ever constantly closer together, it would be a national scandal for a large portion of our coal reserves to remain unusable in the ground because we lacked the foresight to so manage our affairs as to acheive a proper balance between fossil fuels and nuclear power.

There is no denying that the trend today is toward nuclear power. In view of the gigantic expenditures made in recent years on nuclear research and development, it would be surprising if this were not true.

My purpose is to urge that in developing our nuclear future we do not lose sight of the resource represented by our prolific coal reserves.

While continuing research and development on nuclear power, let us devote more of our money and research talent to coal, also.

U.S. SENATE,
COMMITTEE ON PUBLIC WORKS,
January 16, 1967.

The PRESIDENT,
The White House.

DEAR MR. PRESIDENT: In the State of the Union message to the 90th Congress, you admonished that "We should vastly expand the fight for clean air with a total attack on pollution at its sources * * *." I agree, and I recommend the purposefulness of that statement. It is my hope that we resort to the same definition "sources" on which to center pollution abatement attention.

I feel that we must avoid economy-destroying actions while seeking to develop technology at the maximum rate of capability.

There should be emphasis on developing new fuel burning methods and equipment, as well as stepped up efforts to find ways to screen out or trap or absorb the harmful and offensive smoke stack gasses and particulate emissions as means to the end of materially minimizing air pollution and eliminating it in every possible area. These are the affirmative types of activities on which government and industry should be centering much attention because, without such actions, regulations and criteria for air pollution control will be virtually unaccomplishable and relatively unrealistic.

We know that there is much being done in research to improve technology bearing on air pollution. Sulfur oxide problems are being attacked—but not enough. The automotive manufacturers and the petroleum industries obviously are centering more attention on efforts to achieve low emission vehicles—but is the effort being expended at the maximum rate of capability? Our Senate Public Works Committee has a specific schedule of inquiries in this particular field, and I hope we will find more progress and more reason for optimism than is publicly apparent.

There seems to be a substantial emphasis by the air pollution control policymakers and administrators on limiting sulfur oxide emissions—even more so than on other gases and on particulates. And there appears to be a tendency to rush regulation proposals and criteria development and dissemination faster than technology can be brought to bear on possible solutions to problems which perhaps bar compliance with the proposed regulations and standards (criteria). Fuel supply and energy distribution chaos, as well as sharp upward thrusts in the cost of living index due to consumer fuel and energy cost increases, could be direct results of precipitous programs to outlaw all but very low sulfur fuels or all but those not emitting sulfur oxides. Hasty restrictions might even create severe fuel and energy shortages and safety hazards in some areas.

So, Mr. President, I urge that there be the earliest possible emphasis placed on research and development directed toward achieving substantial break-throughs in the technology of entrapment and possible recovery of sulfur in the stacks, especially those of the coal or oil burning electric generating plants. In the interest of expediting such a course of action, I suggest that a larger role be assigned to the Bureau of Mines of the Department of the Interior and that the Bureau be funded for such purpose as promptly as possible to proceed on a full capacity basis. And I have the feeling that private industry would subscribe monetarily and cooperatively to the Bureau of Mines effort in this field, possibly through such instrumentalities as the American Petroleum Institute, the National Coal Policy Conference, Bituminous Coal Research, Inc., and the Edison Electric Institute.

I am an advocate of air pollution control, but I believe it must be a progressive movement accomplished in an orderly and realistic manner. We must not inflict dislocation and chaos on substantial elements of our economy if they demonstrate cooperativeness but are held back by technology gaps. I know that clean air will be expensive to achieve but we must be careful not to make inordinate increases in the cost of living index. The real answers to air pollution abatement will be found in regulations and criteria kept in balance with technology and supply.

It is recommeded, Mr. President, that we make an inventory of technological shortcomings which inhibit in substantial degree the accomplishment of a condition of clean air and that we make vigorous efforts to advance more rapidly in the field of technology bearing on air pollution control. It is my feeling, based on information available, that there is a capability in the Bureau of Mines to accelerate the research and development of methods to trap sulfur oxide emissions in stacks and possibly to capture usable sulfur—which is in short supply. This is doubtless only one of numerous areas on which technological emphasis should be placed in the interest of abating air pollution—but it is a critical area and a sensitive pressure point at which to begin a more adequately financed and more aggressive effort to achieve clean air.

Respectfully submitted.

JENNINGS RANDOLPH, *Chairman.*

Senator BOGGS (presiding). Dr. Hibbard, Director of the Bureau of Mines.

We are happy to have you this morning as a witness and ask you to proceed, sir.

STATEMENT OF DR. WALTER R. HIBBARD, JR., DIRECTOR, BUREAU OF MINES, DEPARTMENT OF THE INTERIOR; ACCOMPANIED BY HARRY C. ALLEN, JR.

Mr. HIBBARD. Thank you.

My name is Walter Hibbard and I am the Director of the Bureau of Mines, U.S. Department of the Interior. A biographical summary is available for the record, if you so desire.

I am most appreciative of the opportunity to appear before this subcommittee to discuss our alkalized alumina process for the removal of sulfur from flue gases, including the limitations of the state of the art and the economics involved in applying the process on an operational basis.

The Bureau of Mines has been involved in research aimed at the removal of sulfur oxides from flue gases associated with the extraction, production and utilization of minerals and fossil fuels for nearly 50 years. For the past 10 years, the emphasis has been directed toward the removal of sulfur oxides from the flue gases resulting from the combustion of fossil fuels inasmuch as this source of sulfur oxides represents a major contribution to air pollution in urban areas.

A decade ago, the only known SO_2 removal systems were wet processes producing various concentrations of sulfuric acid. Such processes are known to be commercially successful when applied to stack gases from smelters processing sulfide ores.

I might add, parenthetically, that the sulfur content of these smelter flue gases is high and that in general these plants are associated with fertilizer production where superphosphate is produced by the use of sulfuric acid.

However, there are serious drawbacks when these processes are applied to the flue gases emanating from powerplants. It is preferable

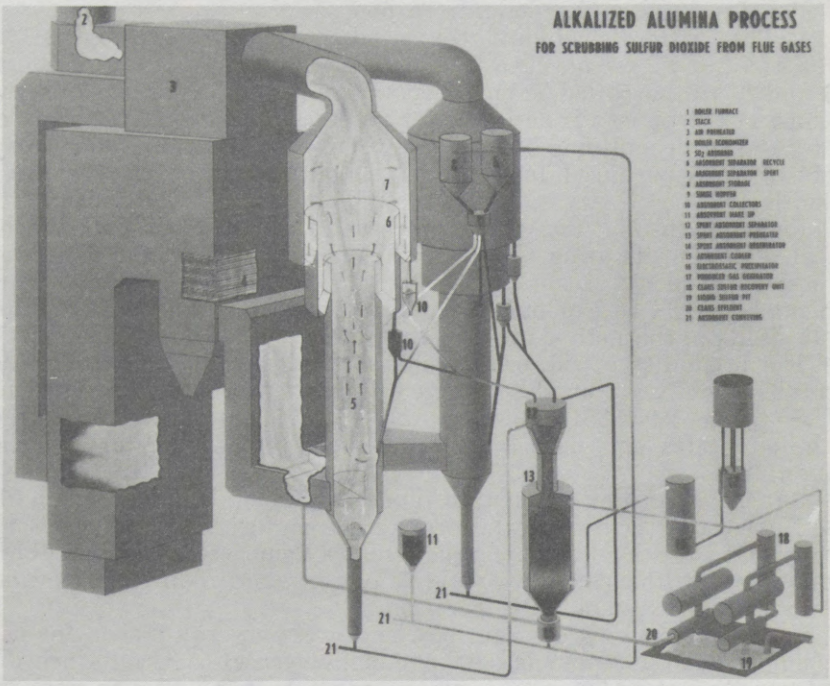
to use absorbents in the dry state which permits adequate dispersement of the flue gas after removal of the sulfur oxide content.

The Bureau of Mines developed a research program and requested funds from the Public Health Service to initiate studies on the desulfurization of fuels prior to burning and on the removal of sulfur oxides from flue gases prior to their discharge into the atmosphere. Support of this very important work started at $42,000 in 1959 and in the present fiscal year is $310,000.

Initial studies indicated that the latter method would be the more economically feasible, so the Bureau of Mines program has emphasized this approach to the solution of the problem.

The program has led to the development of the alkalized alumina process which has been granted a U.S. patent with the patent rights assigned to the U.S. Government as represented by the Secretary of the Interior.

This morning I should like to describe this process to you, assess its state of development, compare it with other processes currently being developed, and present future plans for completion of the program. I think each of you have a small copy of the chart. This represents a boiler where the fuel is being burned.



The gases from the boiler go over to a heat exchanger and down through a reaction chamber. This reaction chamber is about 50 feet high and about 10 inches in diameter. There is a counter current flow of alkalized alumina. Here is a sample of the alkalized alumina. It is a raw form of a well-known antiacid stomach distress remedial com-

pound so it contains fairly common materials, it is highly absorbent, and we use it actually in a pelletized form, about 1/8 to 1/4 inch pellets.

These are dropped through the chamber; the sulfur dioxide is absorbed into the pellets and the remaining gas then passes on its way out the stack. The pellets are collected at several locations.

Incidentally, this is a second path of exactly the same thing here. The pellets go to a chamber where producer gas or some reducing gas in the form of hydrogen or carbon monoxide or a combination of both passes counter current through the bed. This regenerates the absorbent that then can be used again and forms hydrogen sulfide as a gas which can be converted into sulfur by a standard Claus converter.

The process under development at the Bureau of Mines consists of four steps:

1. Absorption—alkalized alumina is contacted by the flue gas to remove sulfur oxides.

2. Regeneration—the alkalized alumina containing the sulfur oxides is treated with a reducing gas to convert the alkalized alumina to its original state for recycling in the process. The sulphur oxides are simultaneously converted to hydrogen sulfide.

3. Production of reducing gas—a gas generator is required to supply the gas used in step 2. The required gas may be produced from coal, natural gas, or heavier hydrocarbons.

4. The hydrogen sulfide is converted to elemental sulfur.

Steps 1 and 2 are novel to the alkalized alumina process while steps 3 and 4 are borrowed from other existing commercial scale operations. If the process is designed for 90 percent removal of sulfur oxides and coal containing 3 percent sulfur is burned, then 1 ton per day of sulfur is produced for each 4.3 megawatts of power generated per day.

Research on this process has proceeded through laboratory bench-scale experiments using simulated flue gases. Based on the results of these experiments, a small pilot plant was built and operated. This plant burned 1 to 5 pounds of pulverized coal and showed the applicability of the method to actual flue gases.

The feasibility of the processes was established by the bench-scale studies. This work on the alkalized alumina process has resulted in U.S. patent 2,992,884 issued on July 18, 1961, and assigned to the United States of America as represented by the Secretary of the Interior.

After a year's delay to obtain funds, a larger pilot plant was built to further test the process and provide the engineering data necessary to permit the design and construction of a demonstration plant. This pilot plant, with a capacity equal to a powerplant producing 0.2 megawatts, has just been put into operation.

The plant consists of a furnace and accessory equipment for the combustion of 165 pounds per hour of pulverized coal, a 10-inch diameter absorption tower 50 feet high, and a 24-inch diameter regenerator. The plant is completely instrumented for automatic control and is designed to operate for extended periods on a 7-day-a-week, 24-hour-a-day schedule. This larger pilot plant will enable:

1. The study of the operability of the process on a continuous basis.

2. The study of absorber attrition loss and the absorption lifetime of the alkalized alumina in the recycling process.

3. The collection of engineering and design data necessary for plant scale-up.

4. The evaluation of the performance of alkalized alumina with varied physical and chemical properties.

This pilot plant is in operation today. We cordially invite the subcommittee to visit our research center near Pittsburgh to observe its performance.

The principles of this process have been adopted by the Central Electricity Generating Board, Great Britain, and since October 1961 they have had a continuing development program to study this process. They have installed a small alkalized alumina pilot plant on an operating coal-burning powerplant.

On the basis of the results obtained in operating the pilot plant, they commissioned four engineering companies to make technical and economic studies of the process last year. The favorable results of these studies have led the CEGB to ask for and receive bids for a 50-megawatt installation.

In addition, it is known that the Japanese are also experimenting with the alkalized alumina process, but nothing is known about their progress.

Several U.S. companies and one Canadian company have bench-scale reactors or are installing them to evaluate alkalized alumina preparations while several potential suppliers of the absorbent have research projects on its preparation. It is felt that there will be no problem in obtaining adequate supplies of the absorbent at a reasonable cost.

From this summary of the status of the alkalized alumina process, it is evident that the development of a commercially feasible process has progressed at a greater rate in Great Britain than it has in the United States. The scale-up factors, necessary for the design of an acceptable installation for an 800-megawatt powerplant from the present pilot plant are beyond the range of acceptable engineering practice.

Engineering practice dictates the need for a prototype plant in the range of 30 megawatts. Normally, it would be recommended that any further development await the outcome of the present research program. Because of the seriousness of the situation, and since this process is the most promising, steps should be initiated immediately to design and build a plant to desulfurize a gas stream equivalent to that from a 30-megawatt powerplant.

The urgency of the situation has been emphasized in the President's message to the Congress on preserving our national heritage and his memorandum dated April 21, 1967, to the various Federal departments having air pollution responsibilities. In this memorandum, the President urged the maximum use of the expertise of all Federal agencies, particularly the Department of the Interior's knowledge of the production treatment and utilization of fossil fuels.

The present best estimate is that such a semiworks plant would cost approximately $2.75 million for construction and operation for a period not to exceed 2 years. This proposed approach involves a degree of risk because only small-scale pilot plant data are presently available for the Bureau of Mines alkalized alumina process.

However, it is estimated that the proposed procedure may save up to 2 years in developmental time. Data from the present pilot plant should be available for use in sufficient time to guide the design, construction, and operation of the larger plant.

There has been sufficient indication of interest from industry that it may be possible to build the prototype plant as a cooperative venture between industry and Government. Funds were requested last March from the Department of Health, Education, and Welfare to proceed immediately with the semiworks plant. We have not yet received this funding.

One year ago, Bureau of Mines process engineers made an economic analysis of costs associated with installation and operation of an alkalized alumina desulfurizer on an 800-megawatt electric powerplant. This size plant was chosen because it is representative of the size of many powerplants now in operation and the size of most of the plants contemplated in the near future.

There are two other processes for the removal of sulfur oxides from flue gases that are sufficiently advanced in their development so that cost figures can be estimated and compared with the estimates for the alkalized alumina process. The advantages, disadvantages and status of the three processes will be briefly summarized.

The Reinluft process has been developed in Germany. This process uses a char absorbent and produces 100 percent sulfuric acid as a byproduct. Unless there is a ready and convenient market for the acid, this byproduct can be a drawback although the product is of the commonly marketable grade.

The process uses an absorbent that is initially much cheaper than alkalized alumina but its regeneration characteristics are not as good. In addition, there is a fire hazard associated with the absorbent.

The British have shut down their 0.15 megawatt Reinluft pilot plant in favor of the development of the alkalized alumina process and the 5 megawatt installation in Germany will soon be shut down because of operational difficulties.

The catalytic oxidation process has been developed in this country by industry. This system is simpler than the alkalized alumina process and is close to the existing process for the production of sulfuric acid. Furthermore, the research and development on this process is more advanced. However, the byproduct produced is 70 to 75 percent sulfuric acid which has a limited market.

Upgrading this product to 100 percent acid would entail additional costs and have the same marketing disadvantages as mentioned in the discussion of the Reinluft process.

Monsanto Chemical Co. has been in on the development of this process and as they are experienced in the marketing of sulfuric acid, the byproduct disadvantage will be minimized. The process does require clean flue gases to minimize byproduct and catalyst contamination but little is known about catalyst lifetime under actual operating conditions. Furthermore, the corrosion problem associated with the equipment may be difficult or costly to solve. The operation of a 0.2 megawatt catalytic oxidation pilot plant is completed and a 12-megawatt installation will become operational in the fall.

I believe you have people here from Monsanto to testify.

The advantages of the alkalized alumina process are its highly reactive absorbent and the production of elemental sulfur as a byproduct. Sulfur is easily stored or economically transported in comparison to sulfuric acid. The absorbent is expensive and its lifetime is not known with certainty. However, tests performed both by the Bureau of Mines and the Central Electricity Generating Board, Great Britain, indicate this is not a serious factor. I believe their results show a recyle life of the absorbent of 102 times with no loss of absorbing power.

In the United States, at least, the R. & D. is not as advanced as that for the catalytic oxidation process. The estimated economics of the three processes are compared on the chart. This is the capital requirement in terms of dollars for an 800-megawatt powerplant for the Reinluft and catalytic oxidation and alkalized alumina.

Capital requirements and operating costs (800 MW coal powerplant)

Process	Capital requirement [1]		Operating cost [2] (90-percent load factor)			
	Dollars	Dollars per kilowatt	Dollars per year	Mills per kilowatt hours	Dollars per ton of coal	Mills per 10^6 B.t.u.
Reinluft	14,217,000	17.77	5,431,000	0.857	2.45	95.8
Catalytic oxidation	16,999,000	21.25	3,881,000	.613	1.75	68.4
Alkalized alumina	8,510,000	10.64	3,402,000	.534	1.54	60.0

[1] Includes plant cost, interest during construction, and working capital.
[2] Includes raw materials, utilities, labor, maintenance, overhead, and capital charges of 14 percent of total investment but excludes byproduct credit.

In general, our estimates are that the alkalized alumina installation capital costs are smaller. These are the operating costs based on a 90 percent load factor gain with 800-megawatt coal powerplant. It includes plant, raw materials, utilities, labor, maintenance, overhead, and capital charges of 14 percent of total investment but excludes byproduct credit. The byproduct credit is very hard to estimate.

For example, if the sulfuric acid can be fed directly into a fertilizer plant, it might cut the cost significantly. If there is a local market for 100 percent sulfuric acid, at least the advertised market price of $21.50 a ton could be gained. However, it is well known that this price is only sometimes paid; it is an uncertainty in the market.

With respect to the alkalized alumina process, we know that the price of sulfur is around $33 a ton, but again in this particular case it depends on the local need. At the moment, sulfur is in short supply so we believe that sulfur can be marketed any way in the dry form.

In an 800-megawatt powerplant equipped with the alkalized alumina process, using 3 percent sulfur coal and operating to remove 90 percent of the sulfur oxides, 60,000 short tons of sulfur will be produced annually. Assuming a value of $32 per ton for sulfur, $1,920,000 of the total operating cost can be recovered as a byproduct credit.

In areas where sulfuric acid can be readily marketed, an additional investment of $1,950,000 would provide facilities to convert sulfur to the acid and, assuming a sales price of $21.50 per ton for the acid, the byproduct credit would exceed the operating costs.

Again, as I say, these byproduct credits are a matter of local concern and it is very difficult to apply them generally.

Whichever system is used, based on the removal of sulfur oxides from stack gases, it should be borne in mind that applicability to existing plants, particularly in crowded municipalities, may be limited because space is not available for the installation and operation of the necessary equipment.

Estimates of the demand for sulfur by 1980 indicate that the United States will need 6 million tons annually more than the present supply. It is estimated that about 12 million tons of sulfur oxides are lost to the atmosphere each year through the flues of coal-burning powerplants alone. This represents about 6 million tons of elemental sulfur.

The recovery of a significant portion of this sulfur would not only make a tremendous contribution toward the alleviation of air pollution but would also contribute significantly to the solution of a pressing mineral supply problem.

We are continually working to improve the efficiency and economy of the alkalized alumina process. For example, we have found that spent oil shale and red muds of Arkansas and Alabama that result from the production of alumina from bauxite are both very effective absorbers of sulfur oxides.

Since the red muds are now a noxious solid waste, their use as absorbents could solve two problems: A use for the waste product, and the reduction of air pollution.

With the development of an oil shale industry, the disposal of spent oil shale will become a large problem. The problem could be alleviated if it proves feasible to use it as an absorber in the alkalized alumina process.

Nothing is known about the possible byproduct recovery from these absorbers yet, but their use could significantly reduce the initial costs for absorbent in those areas in which these waste products are available.

I might add, to digress, the costs of the alkalized alumina are in these estimates at 25 cents a pound. We believe that this can be reduced to 20 cents a pound which will result in a significant decrease in the annual operating cost. If we can use the red muds and if they are sold to us for essentially transportation costs, this would increase or decrease the cost significantly of the three million four in the operating costs of the estimate for alkalized alumina, $900,000 of this is the costs of the absorbent.

Recently, Professor Teller of Cooper Union has advanced the concept for another process for desulfurizing flue gases. The Bureau is now investigating the technical and economic feasibility of this process.

In any process of reducing air pollution, there will be costs which eventually will ultimately be borne by the consumer. It is our desire to use the long experience of the excellent technical staff of the Bureau of Mines to help in the development of methods and means for holding these costs to a minimum.

I might add there is another process which should have been considered here but we don't have the same kind of data for it. In this process, dolomite added to the combustion chamber removes the sulfur dioxide but does not recover sulfur. The estimated costs for this process

by the company, that is, Combustion Engineering, are approximately 36 cents a ton of coal.

This process has a difficulty in that the volume of fly ash is significantly increased and therefore the fly ash disposal problem is aggravated unless we can find wide uses for fly ash.

In summary, it is believed that SO_2 pollution produced by powerplants can best be controlled by the removal of this contaminant from stack gases by the Bureau of Mines alkalized alumina process—thus permitting and, in fact, encouraging the burning of high sulfur fuels.

This development will also help alleviate the shortage of sulfur and, if new research is successful, it may help resolve the solid waste disposal problem.

Thank you very much.

Senator BOGGS. Thank you, Dr. Hibbard.

Mr. Chairman, do you have any question you want to start with?

Senator RANDOLPH. Dr. Hibbard, I wish to pursue the matter of expenditures and programing on research which I discussed when Mr. Garvey was testifying.

I wrote a letter to the President on January 16, 1967, and I quote from that communication:

> Mr. President, I urge that there be the earliest possible emphasis placed on research and development directed toward achieving substantial breatkthroughs in sulfur in the stacks, especially those of the coal or oil burning electric generating plants. In the interest of expediting such a course of action. I suggest that a larger role be assigned to the Bureau of Mines of the Department of the Interior and that the Bureau be funded for such purpose as promptly as possible to proceed on a full-capacity basis.

Would you care to say what has been happening to this suggestion, if anything?

Mr. HIBBARD. As I mentioned in my testimony, we have asked HEW for more funds to support this scale up. We have not yet received these funds.

Senator RANDOLPH. I have no further questions.

Senator BOGGS. Thank you, Senator Randolph.

Senator Cooper, ranking minority member on the full committee and a member of the subcommittee.

Senator COOPER. Dr. Hibbard, I was very glad to hear your statement this morning. It is technical, but I could understand it to some degree.

I believe you said that if the results of your research thus far on this additive process are borne out, it would remove 90 percent of the sulfur dioxide from the flue gases. Would the resultant flue gases then be tolerable? Would they still constitute air pollution?

To put it another way, if you were able to remove 90 percent of the sulfur dioxide would the flue gases then meet the suggested standards of HEW?

Mr. HIBBARD. Yes, sir. This, of course, would depend upon the sulfur content of coal but if we could take 90 percent out and the 3-percent sulfur coal that would meet their requirement.

Senator COOPER. What would the sulfur content be, then, of coal you would have to use?

Mr. HIBBARD. Well, I could put this in the record. I have not made the calculation but, as I recall, the requirement in New York is something under 1 percent for existing plants and it is scheduled to go as low as five-tenths of a percent eventually.

If we had a 3-percent sulfur coal and took out 90 percent, that would leave about three-tenths of 1 percent in the coals and this would in fact meet their requirements. This suggests that we might be able to treat coal containing up to 5 percent sulfur by this process and from our standpoint as a conservationist the more sulfur in the coal the better we like it because the more sulfur we can recover would thus help alleviate this sulfur shortage.

Senator COOPER. Looking at your chart, you said that the capital requirement to build an alkalized alumina plant would be, I think, $8,510,000.

What percentage of that cost would be attributed to the cost of the equipment necessary for this process?

Mr. HIBBARD. May I put that in the record for you, sir? It is here but it is in a complicated form.

Senator COOPER. Could you just give us a rough idea?

Mr. HIBBARD. I had best read it into the record. The total construction cost would be $7.4 million, 87 percent; 49 percent of it is in the absorber regenerator; 20 percent of it is in the sulfur recovery plant; 7.6 percent is in the gas producer, and then about 10 percent is in the plant facilities and utilities. So, this is the construction cost.

Senator COOPER. I see. In your statement you stated:

> The scale-up factors, necessary for the design of an acceptable installation for an 800-megawatt powerplant from the present pilot plant are beyond the range of acceptable engineering practice. Engineering practice dictates the need for a prototype plant in the range of 30 megawatts.

Is that the plant that is needed, and that you have been asking the Department of Health, Education, and Welfare for funds to construct?

Mr. HIBBARD. Yes, sir.

Senator COOPER. You estimate $2.75 million is needed to construct such a plant and provide for its operation over a period of 2 years. When did you first ask the Department to provide these funds to the Bureau of Mines?

Mr. HIBBARD. We first asked for the funds to start the intermediate size pilot plant in 1963.

Senator COOPER. In 1963?

Mr. HIBBARD. And we asked for the funds for the scaleup in 1965.

Senator COOPER. You asked for the scaleup to $2.75 million in 1965, 2 years ago.

Let me go back to your figures a moment. You have stated that this research program was allocated $42,000 in 1959, and $310,000 in the present fiscal year. Can you give the figures on the money that has been allocated to the Bureau of Mines for this research program beginning in 1959 through today?

Mr. HIBBARD. Yes, sir.

Senator COOPER. What reason has been given to you by the Department of Health, Education, and Welfare against the furnishing of funds for the construction and operation of the prototype plant?

Mr. HIBBARD. You would like a listing of the funds we receive from Health, Education, and Welfare; is that right?

Senator COOPER. Yes, sir.

Mr. HIBBARD. I have it right here. Would you like me to read it?

Senator COOPER. Yes.

Mr. HIBBARD. In 1959, $42,000; in 1960, $45,000; 1961, $75,000; 1962, it was $93,000; 1963, it was $120,000; 1964, it was $145,000; in 1965, it was $235,000; in 1966, it was $270,000; fiscal 1967, it was $310,000; and we don't know what we will get for 1968.

Senator COOPER. What does the Department of Health, Education, and Welfare tell you about your request for $2.75 million for the construction and operation of this prototype plant? What reasons have been given for refusing to make the money available?

Mr. HIBBARD. We don't really have an answer to that question. Last March, we wrote and asked for the funding. We have received an answer, just this week actually, and they said, "Let's discuss it."

Senator COOPER. Mr. Chairman, I would hope that the chairman of the committee would inquire of the Department of Health, Education, and Welfare and find out why it has not made available these funds to the Bureau of Mines.

I am certainly glad, Dr. Hibbard, that you are the Director of the Bureau of Mines and have been working on this problem. I would have greater confidence that solutions would be found if this research could proceed.

I would like to say for the record, Mr. Chairman, that the Department of Health, Education, and Welfare has at times been very critical of private industry, terming it laggard and reluctant to go ahead with research. On the other hand, the Department of Health, Education, and Welfare, while saying to this committee that this problem is very difficult and perhaps right now insoluble, it has refused to make this modest amount of research money available to the Bureau of Mines which has been working in this field, as the Director said, for about 8 or 10 years now.

I think this deserves some inquiry on our part, Mr. Chairman, directed to the Department of Health, Education, and Welfare.

Senator BOGGS. Senator Cooper, I will ask Dr. Hibbard, in these past years if a request for more funds has been made.

Mr. HIBBARD. Would you like to know what we requested each of these years?

Senator BOGGS. Yes, what you requested each of these years.

Mr. HIBBARD. I have it here. Would you like me to read it?

Senator BOGGS. Just supply it for the record. Senator Cooper had asked some of the questions I had in mind to ask you here for the sake of the record.

(The information requested above is as follows:)

Requests from Bureau of Mines to Public Health Service for funding of SO_2 air pollution research:

Fiscal year 1959	$95,000
Fiscal year 1960	104,000
Fiscal year 1961	133,000
Fiscal year 1962	113,000
Fiscal year 1963	160,000
Fiscal year 1964	270,000
Fiscal year 1965	410,000
Fiscal year 1966	460,000
Fiscal year 1967	760,000
Fiscal year 1968:	
Research plant	1,235,000
Prototype plant	2,750,000

Senator BOGGS. Doctor, I wish you would refer to this chart again.

You estimate your costs in round figures based on the 90 percent load factor. I was wondering if there was any point in supplying for the record any variable costs that might be considered.

Mr. HIBBARD. I think it is very difficult because so much of it depends upon performance of the three processes and we don't have the kind of scale-up data we need to do a more sensitive analysis. So, these are really ball park figures.

Senator BOGGS. Very good.

I don't have any other questions, Mr. Chairman; do you?

Senator RANDOLPH. Yes. I have this final question of Dr. Hibbard.

I want to know if you have received any assurance that the Department of Health, Education, and Welfare will allocate any funds for Bureau of Mines work from the $2.75 million 1967 deficiency appropriation. I am wondering if in your discussions you have received any assurances.

Mr. HIBBARD. No, sir.

Senator RANDOLPH. What sum of air pollution control research funds are you actually seeking?

Mr. HIBBARD. We are actually seeking $2.75 million for the scaleup. As of now, we have had no assurance that we will get this funding. In fact, we have made presentations to an industrial firm in the petroleum industry and we hope that if funds are not forthcoming from the Department of Health, Education, and Welfare that we will be able to persuade this company to join us in a joint venture.

We have made this presentation so in fact we think it is important to go ahead with this and we will work with anyone who has the resources and the interests to help us.

Senator RANDOLPH. I don't think we should stand back, Dr. Hibbard, because somebody says we don't know this process is going to work. We have to go on the assumption that several of these projects are going to be a part of this program. I am not attempting to be a carping critic this morning but I think there has to be some money reserved for you in this research program in fiscal year 1967 and I think it has to be allocated to the Bureau of Mines.

I am very frank to make that statement because I think that you are capable and you are ready to move forward.

Now, what about the additional $15 million we are thinking about for fiscal 1968? We are not seeming to get very far, are we?

Mr. HIBBARD. Well, sir, you may recall that the Bureau of Mines was not given any direct funding in this field. The decision has been made that this will be handled through the Department of Health, Education, and Welfare, so we do not have funds for this purpose; we have to go to them for it.

Senator RANDOLPH. We may have to put some money in S. 780 for it; we may get to that.

Go ahead, sir.

Mr. HIBBARD. So, our negotiations have all been with Health, Education, and Welfare.

Needless to say, I am raring to go; I think we can put some zing into this process and make it work. I am just anxious to get it started by any means.

Senator RANDOLPH. Dr. Hibbard, you are saying you don't want to stand on the sidelines, is that right?

Mr. HIBBARD. Excuse me, sir.

Senator RANDOLPH. I remarked that you are saying you do not want to stand on the sidelines.

Mr. HIBBARD. No, sir.

Senator RANDOLPH. You want to be in the game, playing the game.

Mr. HIBBARD. Yes, sir.

Senator RANDOLPH. And hopefully winning the game in reference to the program for control of sulfur emissions.

Mr. HIBBARD. Yes, sir. I think this is an extremely serious problem. I think it can be solved technologically. I think it can be solved faster if we play all of our cards at once. I think we have a card to play and I would like to be in there playing.

Senator RANDOLPH. There are apparently no newspaper people present, but I wish they could hear what you are saying today because there are some people who think the Bureau of Mines program of research is of little concern to the bureau you head so capably—that it is a concern to Health, Education, and Welfare.

I saw you move forward in your seat when I said that, and I am aware of your interest.

Mr. HIBBARD. Research is my business; that is what I know best.

Senator RANDOLPH. Your face "lighted up" and your countenance seemed to brighten, so to speak. I think this ought to be reflected in the record for the edification of those who are perhaps a little reluctant to feel that you are ready to move forward. I commend you.

Senator BOGGS. Thank you, Mr. Chairman.

Thank you, Dr. Hibbard.

Mr. HIBBARD. Thank you.

Senator BOGGS. Time is running short. It is almost a quarter to 12. We want to move along. We appreciate the other witnesses being here.

I would like to call Mr. Joseph C. Stites, enterprise manager, air pollution control, Monsanto Co.

Mr. Stites, we are happy to have you with us this morning.

Mr. STITES. Thank you, sir.

Senator BOGGS. If you would, just proceed with your statement.

Mr. STITES. Yes, sir.

STATEMENT OF DR. JOSEPH C. STITES, JR., ENTERPRISE MANAGER, AIR POLLUTION CONTROL, COMMERCIAL DEVELOPMENT DEPARTMENT OF THE INORGANIC CHEMICALS DIVISION, MONSANTO CO., ST. LOUIS, MO.; ACCOMPANIED BY CECIL UNDERWOOD, OF WASHINGTON, D.C., REGIONAL VICE PRESIDENT OF MONSANTO CO.; RALPH F. BOVIER, OF JOHNSTOWN, PA., VICE PRESIDENT-TECHNICAL, PENNSYLVANIA ELECTRIC CO.; AND JOHN G. MILLER, OF READING, PA., CHIEF ENGINEER, METROPOLITAN EDISON CO.

Mr. STITES. Mr. Chairman and members of the subcommittee, I am Dr. Joseph C. Stites, Jr., enterprise manager, air pollution control, in the commercial development department of the inorganic chemicals division of Monsanto Co. in St. Louis, Mo.

With me today are Mr. Cecil Underwood of Washington, D.C., regional vice president of Monsanto Co.——

Senator BOGGS. Let me interrupt you and pay my respects to Mr. Cecil Underwood, former Governor of West Virginia. I had the privilege of serving with him while it was my privilege to be Governor of Delaware. We are glad to have Governor Underwood with us today.

Mr. STITES. Thank you.

Mr. Ralph F. Bovier of Johnstown, Pa., vice president-technical, Pennsylvania Electric Co., and Mr. John G. Miller of Reading, Pa., chief engineer, Metropolitan Edison Co.

Both of these companies are subsidiaries of General Public Utilities Corp. of New York City.

We are here in response to your invitation to discuss our work on the catalytic oxidation process for the removal of the sulfur value from flue gases as a means of controlling or abating air pollution from combustion processes.

Over 6 years ago, Pennsylvania Electric Co., Air Preheater Co., Research Cottrell Corp. and Monsanto Co. participated in the construction and operation of a small pilot plant at Pennsylvania Electric's Seward, Pa., generating station.

I might interject here that the motivation for this cooperative program came from several sources. Pennsylvania Electric Co. is located in the heart of the soft coal producing area in Pennsylvania and burns sulfur-containing coals as fuel in its generating stations.

Air Preheater Co. and Research Cottrell Corp. are suppliers of equipment to the power industry.

Part of Monsanto's business estate lies in the manufacture of catalyst and in the design and construction of process plants relating to the oxidation of sulfur and sulfur compounds and the manufacture of sulfuric acid.

The purpose of the pilot plant was to demonstrate the technical feasibility of a process that would catalytically oxidize sulfur dioxide, in low concentrations found in flue gases, to sulfur trioxide.

Upon cooling, the sulfur trioxide would react with water vapor in the flue gas and condense as sulfuric acid, which could be collected.

Operation of the pilot plant achieved its intended purpose of demonstrating the technical feasibility of the process, but it left many questions unanswered. The pilot plant did not use commercial type equipment, so that scale-up to commercial units would be extremely difficult. The most economically feasible materials of construction had to be found. Engineering and operational details had to be developed. Heat and material balances had to be determined. Economic feasibility had to be proven. We needed a larger plant, made of commercial type equipment, to obtain more meaningful measurements. However, to build a larger pilot plant would require the expenditure of a significant amount of money.

To make a long story short, after much soul searching, many calculations and estimations, and many meetings with interested agencies (both inside and outside the Federal Establishment) to determine the need for solution to the problem, Monsanto and Metropolitan Edison Co., as mentioned before, an associated company of Pennsylvania Electric Co., decided to cooperate in the building of a prototype plant.

The site chosen for the prototype plant was Metropolitan Edison's Portland, Pa., generating station. This is a large, modern generating

station burning a variety of bituminous coals obtained from many sources.

It is a baseload plant and, therefore, is on stream for a large percentage of the time. It is an ideal location for the experimental units.

Design and procurement of equipment started last spring. Construction commenced last October and is scheduled for completion in June 1967, next month. We hope to start plant operation during July.

The prototype plant is designed to treat about 63,000 actual cubic feet per minute of flue gas which represents about 6 percent of the total flue gas from the Portland Unit No. 2. The Portland Unit No. 2 has a generating capacity of 250,000 kilowatts.

Although the prototype plant takes only a portion of the total flue gas from the generating station, it incorporates commercial type equipment about the size used in many industrial boilers.

Our present technology indicates that the process will be adaptable not only to coal-fired but also to oil-fired boilers and to a range of sizes from the largest power stations to small industrial boilers.

The process as it now stands involves taking hot flue gases directly from the boiler at 900°F. (chart 1) and passing them first through a highly efficient hot electrostatic precipitator to remove fly ash. This precipitator is designed to remove 99.5 percent of the particulates from the gas stream. The gases are then passed through a converter where the sulfur dioxide is catalytically oxidized to sulfur trioxide.

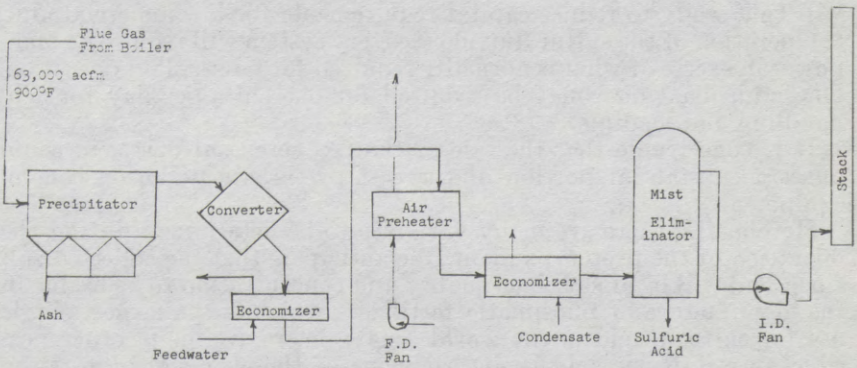


Chart 1

TENTATIVE

SCHEMATIC FLOW SHEET

From the converter the gases are passed through a series of heat exchangers to recover heat and send it back to the boiler cycle and to cool the gases so that the sulfur trioxide can react with water vapor to produce sulfric acid.

Some of the acid condenses on the surfaces of the heat exchangers but most of it is produced as a mist which is collected and removed from the system by a highly efficient brink mist eliminator which is a Monsanto development currently being used in many industrial applications to remove mist from gas streams.

The prototype plant is designed to remove all of the fly ash, 90 percent of the sulfur dioxide from the flue gas, and over 99.5 percent of the sulfuric acid produced.

We anticipate that the sulfuric acid produced will be of marketable quality. The purity of the collected acid should be acceptable for commercial uses. The concentration will be a function of plant operation.

This project is still in the development stages and many questions remain to be answered. However, we hope to have sufficient information available by the end of 1967 to start the design and sale of commercial units.

Until the process is demonstrated and engineering details are determined, it will be difficult to determine the cost of such an installation.

However, preliminary calculations indicate that a new, large generating station could incorporate a sulfur recovery system for an installed equipment cost of $15 to $24 per kilowatt over and above the cost of a conventional station.

This represents a 15- to 25-percent increase in capital for a generating station.

We believe that the system can also be installed in existing plants. To attach the sulfur recovery system to an existing generating station would cost $23 to $32 per kilowatt. The reason the add-on unit is more costly is that some existing equipment would be obsoleted and new equipment substituted.

Of prime importance during the operaton of the prototype plant will be a study to reduce capital requirements for a commercial unit.

Operation of the sulfur dioxide recovery system will require no manpower in excess of what is normally required for powerplant operation. One additional man may be required for one shift per day for acid handling and loading.

It is conceivable that the sale of the recovered sulfuric acid could offset a substantial portion of the cost of the air pollution control equipment.

Here again, there are many variables to be determined during the operation of the prototype plant. We anticipate that the collected sulfuric acid will be of sufficient quality and concentration to be usable in the manufacture of phosphatic fertilizers which is the largest single use for sulfuric acid in the world today. There are many other possible uses. Sulfuric acid is the backbone of the chemical industry.

Economic attractiveness of the process will also be enhanced by the use of low cost, high sulfur fuels. The process is expected to operate more efficiently when the high sulfur fuels are used.

This fact in itself could benefit the coal mining industry which is presently facing some serious problems in furnishing low sulfur fuels to meet existing and pending legislation.

There are other possible applications of the SO_2 recovery system as a means of abating air pollution. Although we have limited our discussion to coal-fired generating stations, we believe that the system will be equally applicable to oil-fired boilers. Other applications which we are studying include industrial boilers, oil and metal refineries and papermills.

Since Metropolitan Edison and Monsanto first announced intentions of building the prototype plant, we have received inquiries from

all parts of the world and from many different industries. The United States is not alone in its air pollution problems.

Those of us who are working on the project have a high degree of confidence that we can take it to a successful conclusion.

However, we must emphasize that it is still under development and that a lot of hard, experimental work is yet to be done. Both Metropolitan Edison and Monsanto are contributing not only money, but the very best talent we have available to us.

Together, the two companies will spend between $4 million and $5 million for the project, including backup research and development—all, of course, without any taxpayer's support or guarantee of payout.

If the project is successful, we believe we can make a substantial contribution toward solving a very serious air pollution problem.

Furthermore, we believe we can assist the coal mining industry by providing a means by which high sulfur coals can continue to be used.

Last, but not least, we hope we can accomplish this with a minimal additional cost of generating electricity.

It has been a pleasure to be here today, Mr. Chairman, and I will be most happy to try to answer any questions that you may have.

Senator BOGGS. Thank you, Mr. Stites.

Senator Randolph.

Senator RANDOLPH. Not at this moment, sir.

Senator BOGGS. Senator Cooper.

Senator COOPER. I just wish to commend Mr. Stites on his presentation.

Are you an engineer, Mr. Stites?

Mr. STITES. I am a chemist.

Senator COOPER. I admire the ease with which you deal with this subject. According to your statement, you have gone quite a distance with this process.

Mr. STITES. We are in the final stages of construction now; yes, sir.

Senator COOPER. Would a coal burning plant, with the installation of the equipment you have described, have serious problems of additional costs? Would it have problems of competing with other fuel sources in the economic production of electricity? For example, would it still be competitive with a gas or oil plant?

Mr. STITES. This, of course, would be a function of location of the plant with respect to the coal field but coal today is still about our lowest cost form of energy in the United States. That is a fossil fuel.

Senator COOPER. You don't see any problem there?

Mr. STITES. No, sir.

Senator COOPER. I have no further questions.

Senator BOGGS. Mr. Stites, could you estimate about how long a period you would have to operate your prototype plant before you could come to a conclusion, so to speak, as to its commercial availability, so to speak?

Mr. STITES. We are planning to operate the plant for a minimum of 1 year. However, we think that by the end of 4 or 5 months we will have sufficient operational data that we would be in a position to start process design for commercial units.

Senator BOGGS. Could you indicate whether to your knowledge Monsanto would be in a position to utilize research and development

funds which might be available under Senator Randolph's amendment 181, or would you prefer to carry it on as a private project as you are now doing?

Mr. STITES. We would prefer to carry it on as a private project now because we have a tremendous amount of what we consider to be proprietary information that we are utilizing in the process.

Senator BOGGS. I suppose that might answer this question, too, if you care to comment on it.

Could you indicate what is the position of your company relative to any patents which might result from research efforts?

I suppose your answer to the first question more or less answered that.

Mr. STITES. Well, not really. We have applied for a patent but have been told by the Patent Office that no patent that would afford us an exclusive position will be issued.

Senator BOGGS. I see.

If there are no further questions, Mr. Chairman——

Senator RANDOLPH. Senator Boggs.

I want to return to your prepared testimony and want you to underscore for our thinking the words "Economic attractiveness of the process will also be enhanced by the use of low-cost high-sulfur fuels. The process is expected to operate more efficiently when the high-sulfur fuels are used."

Now, will you break that down just a little, sir?

Mr. STITES. Yes, sir.

Part of the economic attractiveness of the process will be due to the recovery of sulfuric acid and its sale. The more sulfuric acid that is collected, the more you have for sale and the more dollars you would generate to help pay off the cost of operation.

So, we think that high-sulfur fuel will contribute significantly to the possibility of recovering moneys required to build—or invest in—and operate the process. This is a catalytic process and, as most catalytic processes do, it operates most efficiently when it has a lot of fuel to burn. In this case, the sulfur dioxide is the fuel and we think that we will get a higher conversion of sulfur dioxide to sulfur trioxide when we are working with stronger gas streams. We get these from burning high-sulfur fuels.

Senator RANDOLPH. Then I do agree with you and your further statement that this, in itself, will be a benefit to the coal industry. I think this is a valid statement.

I thank you very much for your contribution to our hearing today and I join with my colleagues in commending you on your presentation.

I think it is very important that the private segments of a broad scope of industry in this country do what you are doing in Monsanto and that is to make a definite contribution in the field in which you feel you are best equipped, we will say, by experience and by the background of productivity to make this contribution. You are doing that; is that correct?

Mr. STITES. Yes, sir.

Senator RANDOLPH. Thank you very much.

Senator BOGGS. Thank you very much, Mr. Stites.

Senator BOGGS. Mr. Jonakin, assistant manager, Kreisinger Development Laboratory, Combustion Engineering Corp.

Mr. Jonakin, we are very happy to have you here this morning.

STATEMENT OF JAMES JONAKIN, ASSISTANT MANAGER, KREISINGER DEVELOPMENT LABORATORY, COMBUSTION ENGINEERING, INC., WINDSOR, CONN.

Mr. JONAKIN. Thank you, Mr. Chairman.

We appreciate the opportunity to appear before your committee and discuss our work in air pollution.

I am accompanied by John Murphy and Robert Lowenstein, attorneys for Combustion Engineering.

Recognizing the need for a commercially practical system for the reduction of sulfur dioxide emission from utility boilers, Combustion Engineering, Inc., initiated a research program to develop a low-cost, high-efficiency process.

Removal of sulfur from the fuel before burning as well as the removal of sulfur dioxide from the stack gas were reviewed by Combustion before deciding on a specific experimental program.

REVIEW OF DIRECT FUEL DESULFURIZATION PROCESSES

Accurate cost data for direct removal of sulfur from commercial fuels are not readily available, but in general it can be stated that all available methods are extremely expensive.

An extensive study of methods for desulfurizing residual fuel oil has been published by the U.S. Bureau of Mines.

The most promising method studied was hydrodesulfurization. Cost estimates for this process vary from 40 cents to $1 per barrel of fuel oil. This represents an increase of 20 to 50 percent in the price of residual oil.

Generalized data on costs for direct sulfur removal from coal are even harder to obtain because of the wide difference in the sulfur forms existing in different coals.

Mr. Garvey discussed those different forms.

Organic sulfur, which comprises 40 to 60 percent of the total, is an integral part of the coal structure and cannot be removed by mechanical cleaning. Pyritic sulfur accounts for most of the remainder. Pyritic sulfur that is found as large aggregates can be removed effectively; however, finely divided pyritic sulfur is not readly removed by coal cleaning procedures.

The amount of pyritic sulfur that can be removed varies so greatly that generalizations on the extent of sulfur removal and costs are of little value.

REVIEW OF SULFUR DIOXIDE REMOVAL PROCESSES

Over the years, much work has been done on the second approach, that of removing sulfur dioxide from the stack gases. Several processes are now being considered, and you just heard several of those discussed.

Most advanced of these are (1) the Reinluft process, (2) the alkalized alumina process (Bureau of Mines), and (3) the catalytic oxidation process (BCR-Pennsylvania Electric).

All these processes involve the production of elemental sulfur and/or sulfuric acid. They also appear to be extremely expensive.

OBJECTIVES AND PROPOSED PROCESS

After studying the various sulfur dioxide removal processes, it was concluded that a system most acceptable to the utility industry would probably be one that did not involve the operation of chemical recovery equipment and one that could improve operating performance of the powerplant.

A system utilizing an additive, that could neutralize the corrosive combustion products and that would form a disposable compound with the sulfur, was thought to be a logical approach.

Studies by Wickert, others in Germany, and Wisconsin Electric indicated that alkaline earth additives (dolomite, limestone, and so forth) are reactive in varying degree with sulfur oxides.

Since studies conducted by our research department have indicated that such additives can prevent high- and low-temperature corrosion in boilers, it was decided to explore the possibility of developing a system using dolomite or limestone.

The following objectives for a combination sulfur dioxide and dust removal system were established:

1. A system not dependent on the sale of a chemical.

I may insert, we did not think the chemical industry should be a part of the utility field. In talking to many of the utility companies this was their view.

2. Reduction of sulfur dioxide and particulate matter to such a level that stack height and cost could be reduced.
3. Use of a wet scrubber for both sulfur and dust removal.
4. Increased potential boiler thermal efficiency without corrosion.
5. Reduction of high temperature coal-ash or oil-ash corrosion.

The system developed by Combustion Engineering, Inc., to fill these requirements is shown in figure 1.

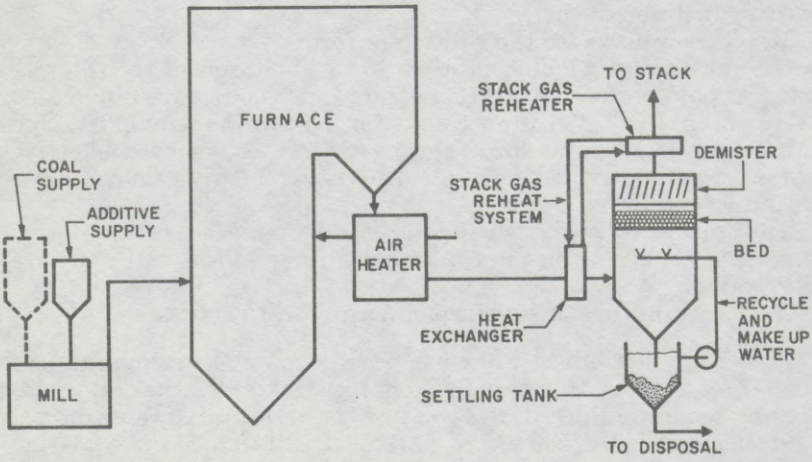


FIG. 1 SCHEMATIC OF SO_2 REMOVAL SYSTEM

This system involves the feeding of an additive (dolomite) into the furnace and wet scrubbing the flue gas leaving the air heater.

The dolomite fed into the furnace is calcined by the heat of the furnace producing a more reactive compound; any deposits formed on high temperature surfaces are noncorrosive; and the calcined particles react with the sulfur trioxide (SO_3) in the flue gas thus preventing low-temperature corrosion.

By use of a scrubber, the calcium and magnesium oxides are dissolved in water, and the sulfur dioxide in the flue gas reacts to form sulfates and sulfites of calicum and magnesium which, in turn, are precipitated in the wash water.

In addition, the fly ash is simultaneously scrubbed from the flue gas. Heat added to the stack gases minimizes steam plume formation.

LABORATORY STUDIES

In order to determine the feasibility of removing sulfur dioxide and particulate matter from gases in a wet scrubber, a laboratory pilot plant was constructed and tests were run.

A controlled amount of sulfur dioxide, additive, and fly ash was added to the stack gas of a natural-gas-fired boiler and then the mixture passed through a wet scrubber. The gas was sampled before and after the scrubber to determine the removal efficiency.

The results are shown in table 1. Ninety-eight to ninety-nine percent sulfur dioxide removal and 98 to 99.6 percent dust removal were obtained.

TABLE I.—*SO_2 removal, calcined dolomite (laboratory results), dry additive to gas stream*

Material fed	Dolomite	Dolomite	Dolomite and fly ash
Dust loading, gr/SCF	3.2	3.2	6.6
Gas flow, cubic feet per minute	1,000	935	935
SO_2 removal, percent	98–99	99	99
Dust removal, percent	99.6	99.5	98.0

FIELDWORK

The next phase of the investigation was conducted jointly by Combustion Engineering, Inc., and the Detroit Edison Co. at their St. Clair powerplant.

I might add here that the two companies are dividing the cost in this work.

The objective was to determine whether or not the laboratory pilot data could be confirmed on a commercial-size unit. In addition, furnace operating conditions when injecting dolomite were studied.

In the full-scale tests, dolomite was introduced to one furnace of a 325,000-kilowatt twin-furnace steam generator which is shown in figure 2.

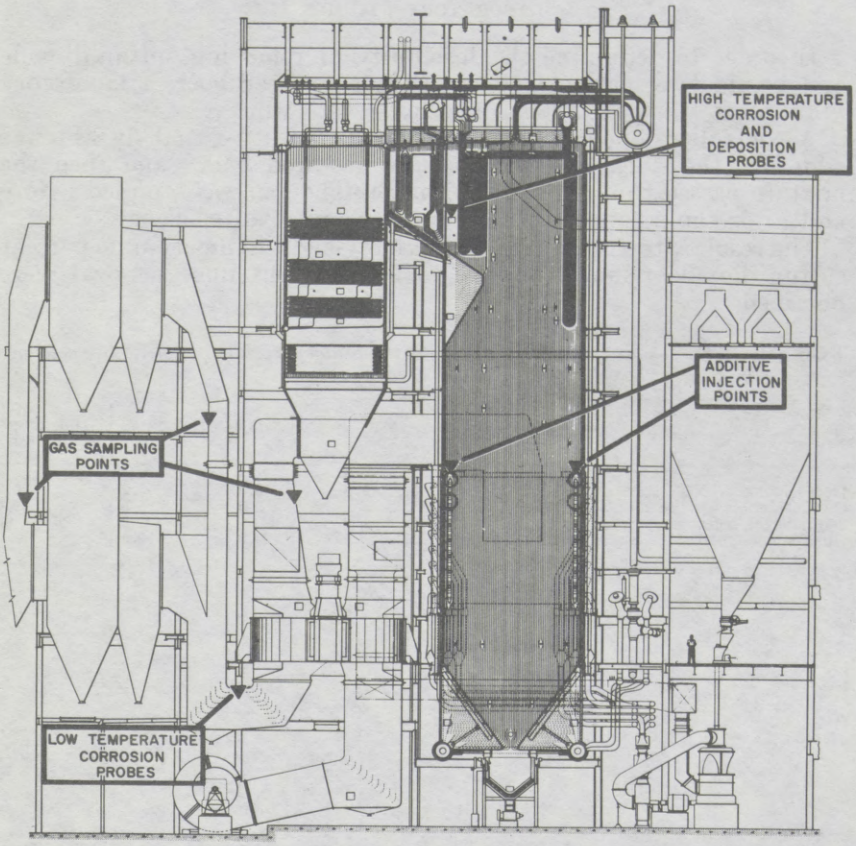


FIG. 2 SIDE ELEVATION OF ST. CLAIR UNIT

Dolomite was injected in sufficient quantity to react with the all the sulfur dioxide produced when coals containing 2.8 to 3.8 percent sulfur were burned.

The other half of the twin furnace was operated at the same firing rate and with the same fuel but without additive or scrubber.

From the furnace in which dolomite was injected, about 3,000 c.f.m. of the effluent gas was withdrawn and passed through a pilot scrubber, which is shown in figure 3.

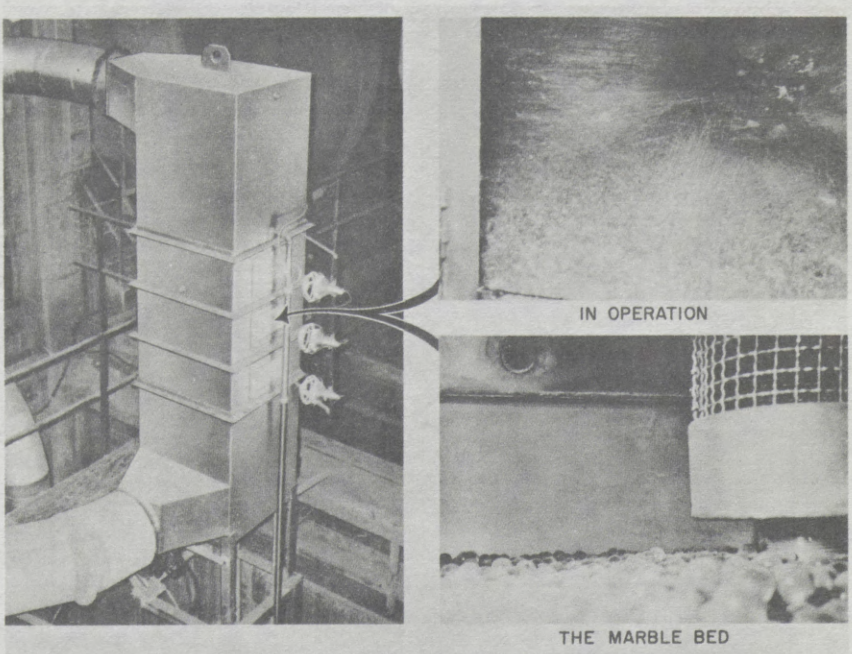


FIG. 3 PHOTOGRAPH SHOWING SCRUBBER INSTALLATION

Dust loading and sulfur dioxide content were determined on the gas entering and leaving the scrubber during test periods. A check of sulfur trioxide content was also made at points before the scrubber.

RESULT AND DISCUSSION—FURNACE OPERATION

Various investigators had speculated that addition of limestone or dolomite to coal-fired furnaces in quantities sufficient to react with the sulfur might cause slagging problems.

Mr. Garvey mentioned that in his discussion.

Excessive furnace slagging would be undesirable because of its detrimental effect on unit capacity and reliability.

However, completely satisfactory furnace operation was obtained while injecting dolomite. No interference with normal steam output occurred during 30 days of continuous addition of dolomite.

HIGH-TEMPERATURE CORROSION TESTS

Corrosion probes were located in the superheater region of both furnaces to determine the effect of dolomite injection on high-temperature coal-ash corrosion.

The results of the tests are shown in figure 4. It can be seen that corrosion is much less in the furnace with dolomite injection.

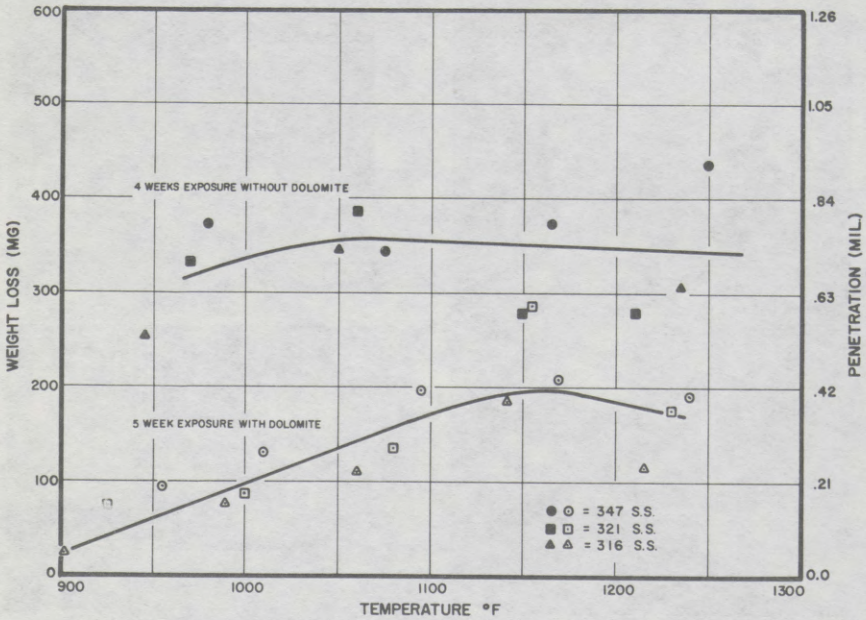


FIG. 4 CORROSION PROBE DATA

In fact, it was about the same as you would obtain with gas phase oxidation.

REMOVAL OF SULFUR TRIOXIDE

Analyses of the gas stream before the air heater showed total removal of sulfur trioxide during the dolomite injection. Since sulfur trioxide forms sulfuric acid which condenses on low-temperature surfaces causing severe corrosion, its removal eliminates low-temperature corrosion problems.

REMOVAL OF SULFUR DIOXIDE AND DUST

Dust removal was maintained at a level of 98 to 99.5 percent during the tests. Typical sulfur dioxide removal data is shown in figure 5.

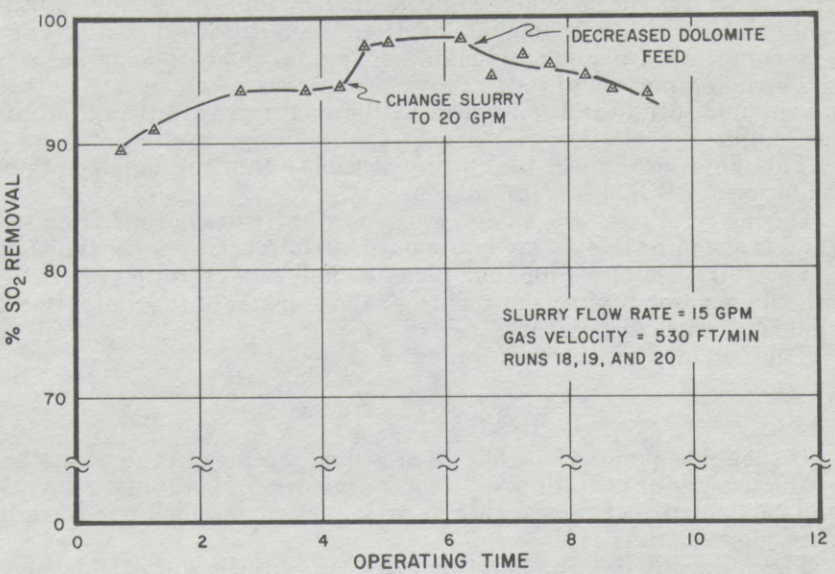


FIG. 5 SO_2 REMOVAL DATA

The data shows that sulfur dioxide removal can be maintained at a very high level (95 percent or better).

With this high level of removal and a fuel containing three percent sulfur, the stack gas concentration of sulfur dioxide would be equivalent to that obtained when burning a coal containing approximately 0.15 percent sulfur.

This concentration is much lower than required by air pollution ordinances that have been passed to date.

It also meets the HEW recommended regulation for the New York-New Jersey metropolitan area which would limit the sulfur in coal burned by existing powerplants to 1 percent and would require new plants to have an assured 20-year supply of fuel with no more than 0.24 percent sulfur. The results obtained will meet all these requirements.

REMOVAL OF NITROGEN OXIDES

During the course of the field tests, an evaluation was made of the effect of the dolomite injection and scrubbing on removal of nitrogen oxides from the flue gases.

This is another air polluter we have to be concerned with. Removal by the scrubber averaged about 20 percent.

SLURRY EFFLUENT

Analytical data on the scrubber effluent indicated that the sludge was about a 1-to-1 mixture of fly ash and dolomite reaction products.

As might be expected, the dolomite reaction product in the sludge from these test runs contained about equal amounts of calcium sulfate and sulfite, with lesser amounts of magnesium sulfate and sulfite, and some unreacted calcium and magnesium oxides and carbonates.

The liquid portion of the scrubber effluent was nearly saturated with magnesium sulfate and contained smaller quantities of calcium sulfate and sulfite.

This fluid is recycled back to the scrubber thus minimizing water pollution and scrubber water makeup.

During pilot tests, the sludge was periodically discharged from settling tanks into the existing bottom-ash settling basin for convenience.

For full-scale operation, our plans include concentration of the fly ash and reaction products in a clarifier and transfer of the concentrated sludge to an ash disposal area.

This will not be a source of water pollution.

COST CALCULATIONS

It should be pointed out that these estimates represent the additional evaluated cost of installing a system for removal of both sulfur dioxide and particulate matter over that of present systems which remove only particulate matter.

The following basic assumptions are made for the cost calculations:

(1) The calculations are based on a 500,000-kilowatt unit burning a coal containing 10 percent ash, 3 percent sulfur, and having a heating value of 12,000 B.t.u. per pound with excess air of 20 percent. An operating time of 8,000 hours per year is assumed.

(2) Power used by the system is charged at 5 mills per kilowatt hour.

(3) Dolomite feed is 110 percent of stoichiometric for removal of SO_2 as either a sulfite or sulfate or 10 percent in excess of that amount needed to react with the sulfur. Dolomite cost is $2 per ton delivered. In Cleveland, dolomite cost is about $1.75 per ton delivered; in New York City it is about $2.24 per ton delivered.

(4) Ash disposal cost is $1 per ton of ash. This varies over the country, in some places it is only 50 cents, in other places it may run as high as $2. For instance, in New York City where they have to barge it out to sea the cost is about $2 per ton of ash.

(5) Fuel cost is 25 cents per 10^6 B.t.u.

(6) Capital charges are 14 percent.

(7) Precipitator cost (installed) is 70 cents per cubic feet per minute and operating power is 0.5 kw. per 1,000 c.f.m.

(8) Stack costs are $1,000 per foot of height for a concrete stack with an independent concrete inner shell and $800 per foot of height for a concrete stack with a steel liner. This gives you some idea of the cost of dispersing SO_2 and particulate matter with tall stacks.

(9) Duct work, engineering, steel work, et cetera, are common to the two systems and, therefore, the cost of these items is not included.

(10) Maintenance and labor costs for the two systems are equal.

Table II contains the estimated net capital cost. You will note that without taking credit for the stack height, no additional capital is needed, but if you take credit for the stack height you have a further savings of about $1.08, which amounts to two-tenths of a cent per million B.t.u.

TABLE II.—*Net capital cost for sulfur dioxide removal*

	Dollars per kilowatt	Cents per 10^6 B.t.u.
Sulfur dioxide removal system equipment additions (scrubber, heat exchanger, pumps and motors, settling tank, mills, etc.)	2.22	
Conventional equipment replaced (dust collector and steam coil)	2.18	
Net capital cost for SO_2 removal	.04	
Capital credits: Reduction in stack height from 800 feet to 300 feet	1.12	
Net capital cost	−1.08	
Fixed charges		−0.20

The net operating cost is shown in Table III. You will note that on a million B.t.u. basis the total operating cost is about 1.5 cents per million B.t.u.

TABLE III.—*Net operating cost*

	Cents per ton coal	Cents per 10^6 B.t.u.
Operating cost:		
Dolomite	24.9	
Added disposal cost	12.8	
Calcining dolomite	3.0	
Power cost	9.0	
Total	49.7	2.05
Credits:		
Corrosion savings	5.3	
Dust collector operation (power)	1.9	
Steam coil operation	1.1	
Total	8.3	.35
Operating cost	41.4	1.70
Fixed charges	4.8	.20
Net evaluated operating cost		1.50

We have taken credits for corrosion savings, dust collector operation by normal means, and elimination of a steam coil which preheats the air to prevent corrosion. A minimum amount of corrosion is experienced with this process. The net cost is 1.7 cents per million B.t.u. not taking credit for reduction in cost for a shorter stack.

When credit is taken for reduced stack cost, the net cost is 1.5 cents per million B.t.u. If it is assumed that we are low by $2 per kilowatt-hour on our capital cost, the net cost would then be about 2 cents per million B.t.u.

It can be seen that the net cost for removal of sulfur dioxide is 1.5 cents per million B.t.u. or about 36.6 cents per ton of coal if operating credits can be fully realized. We think we are quite conservative on the operating credits.

The conclusions that we have reached on this study are as follows:

(1) A coal fired boiler can be operated successfully while adding sufficient dolomite to react with all the sulfur in the coal.

77-515 O—67—pt. 4——17

(2) Sulfur trioxide which forms sulfuric acid is eliminated from the steam generator effluent, resulting in control of low-temperature corrosion and deposit formation.

(3) High-temperature corrosion—which is metal wastage of superheater tubes—is reduced to a minimum by injection of dolomite in the furnace.

(4) By means of a wet scrubber sulfur dioxide removal can be maintained at a high level (95 percent or better).

(5) Particulate matter removal efficiency of 99 percent can be obtained in the same wet scrubber in which sulfur dioxide is removed.

(6) The cost of SO_2 removal for a 500,000-kw. unit is estimated to be 1.5 to 2 cents per million B.t.u. fired.

FUTURE WORK

From the data presented, the removal of sulfur dioxide from stack gases appears to be both technically and economically feasible.

As our next step in the overall system development program, we plan to install two full-size systems—one coal and one oil—to be placed in operation in 1967 or early 1968 on utility steam generators.

The program is expected to confirm that the performance and preliminary cost figures outlined above can be fully realized with a full-scale operation.

It should be recognized that our cost estimates apply to new installations. Estimated costs have been considerably higher as this equipment is applied to existing units.

Thank you, gentlemen.

Senator MUSKIE. Thank you.

On table II I want to be sure I draw the right conclusion. This seems to indicate that in terms of capital cost it is cheaper to install your sulfur dioxide removal system than not to install it.

Mr. JONAKIN. That is correct if you take credit for reduction of stack height from 800 to 300 feet. If you do not take that credit, the two systems will cost about the same.

The assumption that we can reduce the stack height is based on the fact that stack height is used to disperse the SO_2 and particulate matter in the stack gases. If we remove a high percentage of these two pollutants as we have just indicated that we can do, there is no need for the high stack so we have taken credit for a reduction of 500 feet in stack height.

If you did not take that reduction you will note that it would be about $0.04 per kilowatt additional capital cost or about a standoff.

Senator MUSKIE. For a 500,000-kilowatt unit?

Mr. JONAKIN. Right.

Senator MUSKIE. What would that amount to?

Mr. JONAKIN. Not very much money; about $20,000.

Senator MUSKIE. That is what I thought it was.

Now what would it cost applying table III to operate a 500,000 kilowatt unit?

Mr. JONAKIN. 1.5 cents per million B.t.u .fired.

Senator MUSKIE. What would that amount to for a 500,000-kilowatt plant for a year?

Mr. JONAKIN. Per year? I would have to add that later because you have to calculate how many million B.t.u.'s are being fired and multiply the 1.5 cents by this figure.

Senator MUSKIE. If you can give us that figure and also cost per kilowatt-hour.

Mr. JONAKIN. This, Senator Muskie, would be equivalent to, for this particular coal, a 6-percent increase in fuel cost, 25 cents increased by 1.5 cents.

Now to put this on the cost per kilowatt-hour is much more difficult as the cost of fuel is about half the production cost. In addition to production costs, you have distribution costs and many other costs which make this a very small amount of the total but I would be reluctant to say how much, I think a utility company should give you this information.

(Subsequently the following information was provided for the record:)

Assuming a heat rate of 9500 Btu per KW and 8000 hours per year of operation for a 500,000 KW unit, the cost of SO_2 removal would be $570,000 per year.

Senator MUSKIE. Now you are convinced that this is a technically and economically feasible method of eliminating sulfur dioxides in the flue gases. Have you been able to convince any of the potential users that your conclusion is accurate?

Mr. JONAKIN. We have had many inquiries from utility companies. Six have asked for firm proposals on price, four for existing units and two for new installations. The proposals have been sent to these utilities and they are in the process of evaluating them at this time.

Senator MUSKIE. How long has this process been available in this technically and economically feasible form?

Mr. JONAKIN. We finished the 30-day test in Detroit at the end of February. The data evaluation was finished in March and announced to the utilities so they have taken action immediately. I think we have to give them credit for prompt action. They have asked us for firm prices in several instances.

Senator MUSKIE. Now have those utilities which you are seriously considering in your proposals made any independent evaluation of the feasibility of the operation that would be helpful to us?

Mr. JONAKIN. They are in the process of doing that and just how far they have gotten I am not quite sure. However, they are studying the process and we expect to be hearing from them soon.

Senator MUSKIE. Does this process represent any breakthroughs in the state of the art at all?

Mr. JONAKIN. We think it does. The cost is very low as far as SO_2 removal is concerned. Most of the processes that you have heard discussed this morning remove 90 percent of the SO_2. We are talking about considerably more than that and we think this is important. The performance of the equipment is guaranteed. We think the process is that feasible. No doubt mechanical difficulties will be encountered on the first installations, but we can not see anything that is insurmountable so we are guaranteeing these units.

Senator MUSKIE. Have you done any R. & D. work with the support of Federal funds?

Mr. JONAKIN. For the utilities?

Senator MUSKIE. Have you done any?

Mr. JONAKIN. Any for the Government?

Senator MUSKIE. Yes.

Mr. JONAKIN. None on air pollution. We have an OCR project on corrosion in which we are trying to tie in some air pollution work but the SO_2 project was not conducted with Federal funds.

Senator MUSKIE. Do you have any position relative to patents which might be developed as a result of research done with Federal funds?

Mr. JONAKIN. We are of course a member of private enterprise and in research and development it is part of our job to submit for patent study new ideas that we have, and we do consider any new ideas proprietary.

Senator MUSKIE. In other words, your position is the same research if it produces the ideas supported wholly or in part with Federal funds?

Mr. JONAKIN. I think the contract, when you accept Federal funds, stipulates the background patent position that the Government does have a stake in these rights and that you are required to list the background patents. I think this is usually true. I am not an authority on this and really not qualified to reply, but I believe this is true.

Senator MUSKIE. I am not asking you to frame a position here. I simply wanted to ask whether or not you had a position because the question is now almost automatically raised on the floor, if not in the committee, whenever we are involved in the problem of Federal support for research efforts by private industry. What do we do with the patents? Do they go into the public domain or should they? The question is continually raised on the floor in research legislation so I am trying to touch on what I think might be concerned. If you would like to submit a position later, we would be glad to receive one for the record.

Mr. JONAKIN. Would you mind if I do that?

Senator MUSKIE. That will be fine.

(Subsequently the following information was provided for the record:)

Combustion Engineering, Inc., has had many contracts with different Government agencies including the Atomic Energy Commission, the Department of Interior, the Department of the Navy, and the Maritime Commission. Our position on patents, which might be developed as a result of research conducted with Federal funds or which form background for such research, depends on the particular facts of the situation. Included in these facts are the type of research and contract involved and the previous experience of our Company and others in related fields.

Combustion Engineering, Inc. advocates the establishment by Congress of a uniform patient policy for all federal agencies. This policy should include sufficient latitude such that the particular patent provisions of any contract may be established in accordance with the facts of the situation. We believe this can be accomplished by establishing a so-called "license" policy in which the Contractor *retains title* to certain patents with a royalty-free license to the Government for Governmental purposes. Such a "license" policy should apply, for example, when the contract is in a field in which there is significant existing technology.

Exception to this general "license" policy should be included in a uniform patent policy. This would apply in the areas of Government financed basic research and development in uncharted fields in which case the Government would normally take title with freedom to negotiate exceptions to this position. This limited "title" policy would make available to the public the basic patents

in these areas and thus prevent the exclusion of competition and also prevent the stifling of further research and development. There are several disadvantages of a *general* "title" policy, one being the reluctance of private enterprise to develop inventions to the point of commercialization when such inventions are covered by patents owned by the Government.

Another area to be considered relates to the purchase of equipment by the Government which has been developed in the course of research and development efforts financed by the Company and is being offered commercially. An example of this would be the equipment we are offering for the removal of sulfur dioxide and dust from stack gases since our research and development and pilot plant tests have been completed and we are offering this equipment on a commercial basis. We would, therefore, expect to offer this equipment to the Government on the same terms as it would be offered to commercial organizations without relinquishing any patent rights on such equipment.

Senator MUSKIE. Senator Cooper.

Senator COOPER. Is Combustion Engineering, Inc., purely an engineering firm, or does it also manufacture equipment?

Mr. JONAKIN. The primary equipment that we manufacture, Senator Cooper, are steam generating and related equipment, both nuclear and fossil fueled, used by the utilities. Our company produces about 40 percent of the fossil fuel-fired steam generators used by the utility companies.

Senator COOPER. When did you begin this test with the Detroit Edison Co.?

Mr. JONAKIN. This was begun sometime last year, in 1966.

Senator COOPER. Was this a continuous test during last year or up to this time?

Mr. JONAKIN. We had intermittent testing to begin with to optimize conditions under which the scrubber and the system should work and then we ran a 30-day continuous test to determine corrosion rates and how the scrubber and other equipment would operate.

Senator COOPER. I notice you said that in the full-scale test dolomite was introduced into one furnace of a 325,000-kilowatt, twin-furnace steam generator. How many days or months did you continue that test?

Mr. JONAKIN. Thirty days.

Senator COOPER. Was that your longest test?

Mr. JONAKIN. That was the longest test.

Senator COOPER. Do you think that sufficient to arrive at a conclusion to give the committee?

Mr. JONAKIN. We do. We think it is sufficient since the furnace really operated better with dolomite injection than it did previously. The slagging problem was reduced rather than increased by the injection of dolomite.

Senator COOPER. Thank you.

Senator MUSKIE. One other question: You testified as to the reaction of some utilities to your process. Have you had any relation from the coal industry or the oil industry to your process?

Mr. JONAKIN. Yes. We have had talks with Jim Garvey of GCR. We have talked to the Bureau of Mines and others and they have all shown considerable interest in our process.

Senator MUSKIE. Have you formed any judgment in respect to it or do you have any basis for independent judgment with respect to it?

Mr. JONAKIN. I am not sure what judgment they have formed. They have questioned us on such things as water pollution which we question ourselves. They have questioned us on slagging of the furnace and we think we have a good answer for that. There has been no real criticism.

Senator MUSKIE. Has there been any rallying support to your cause? This is what I am interested in. It is a little difficult for me and members of the committee to evaluate this process.

Now the conclusion you have drawn, if it is sound and valid, represents a breakthrough that can shape public policy pretty substantially in this field. I am sure that your testimony is the testimony of a man who knows his business and who has studied this process and has drawn some firm conclusions that makes it valid, but now I am interested in getting the reaction of others upon whom the proposals would have an impact.

Does it generate enthusiasm? Does it generate a high degree of interest? Is there some indication of support for your conclusions? This is the kind of reaction I am trying to get into the record.

Mr. JONAKIN. The Public Health Service has shown considerable interest and is spending some money in this area determining the reactivity of different dolomites in the dry state in particular. They have also, as I understand, made allotments to the University of West Virginia to study disposal problems related to the sludge that we get from wet scrubbing. We are cooperating with them in the study by furnishing samples.

Senator MUSKIE. I wonder if Mr. Garvey is still with us? Is he interested in commenting?

Mr. GARVEY. I would very much like to make a comment for the record about this particular project because we are very enthusiastic about it. Mr. Jonakin and his associates are to be congratulated for a real contribution to the art in connection with this.

As I pointed out in our statement, we have been looking into this approach, especially the part of their work which involves the injection of additives. The work they have done so far, while it is indicative of a logical and successful conclusion, has been on a somewhat small scale and therefore it fits into the testimony I have presented earlier on the need for moving into large scale demonstration plants to put these approaches across.

I think that this has been a contribution to the art. I think it is important not from the standpoint that it is applicable not only to new plants but it is the only approach we can see that might be applicable to existing plants and even to smaller plants than the large 800-megawatt stations we are talking about. To produce salable products with processes such as pointed out by Mr. Stites, you have to really have a large plant to afford the big capital expenditure. This system is relatively simple. I am sure that Mr. Jonakin will agree with me it is applicable not only to the utility plant but some of our industrial plants that burn pulverized coal. I want to go on the record endorsing this approach for the coal industries and urge that we go ahead with it.

Senator MUSKIE. How close in your judgment does it bring us to a widespread application of meaningful control of sulfur oxide gases in the flue stacks?

Mr. GARVEY. I would say that if a demonstration plant on coal is built—this might take a year to 18 months, I don't know exactly how long it takes to get this thing designed and in operation. If someone did this, financed it, did the erection on a full scale plant, assuming 18 months for construction and 6 months for operation, it would prove out some of the problems areas which might exist, the changes needed to overcome the mechanical difficulties that Mr. Jonakin referred to. We could in a couple years have a real commercial process.

Senator MUSKIE. I appreciated that comment, Mr. Garvey.

What is the sludge problem? Say that would be related to 500,000 kilowatts?

Mr. JONAKIN. If you have a 10 percent ash coal this is 200 pounds of ash per ton, if the coal contains 3 percent sulfur this represents 60 pounds of sulfur. It takes about 3 pounds of dolomite per pound of sulfur to neutralize the sulfur, so you are talking about adding 180 pounds of dolomite. Thus you will increase the fly ash from the coal by a factor of about 2.

The ash disposal cost is taken into consideration in our cost calculations. We are paying the extra money to dispose of the SO_2 in a solid form rather than as a gas into the atmosphere. You collect it as a solid and transfer the solid material to the ash disposal area. This does create somewhat of a problem but is necessary in order to prevent pollution of the air with SO_2.

Senator MUSKIE. Thank you very much, Mr. Jonakin. We appreciate your testimony.

Mr. JONAKIN. I am glad to have been here.

Senator MUSKIE. Our next witness, we have two more, is Mr. H. H. Meredith, coordinator of air and water conservation of the Humble Oil & Refining Co., representing the American Petroleum Institute.

STATEMENT OF H. H. MEREDITH, JR., COORDINATOR OF AIR AND WATER CONSERVATION, HUMBLE OIL & REFINING CO., REPRESENTING THE AMERICAN PETROLEUM INSTITUTE; ACCOMPANIED BY C. W. LUBBOCK, MEMBER OF THE TASK FORCE, AMERICAN PETROLEUM INSTITUTE, HOUSTON, TEX.

Mr. MEREDITH. I am H. H. Meredith, Jr., coordinator of air and water conservation for Humble Oil & Refining Co., Houston, Tex., and chairman of the American Petroleum Institute's Task Force on the Economic Study of Caribbean Residual Fuel Oil Desulfurization. It is in the latter capacity that I am here today.

Appearing with me as my backup is Mr. C. W. Lubbock, also with Humble, and a member of the task force who worked more closely with the contractor on highly technical problems than did the chairman.

With the permission of the subcommittee, I would present for the record a written statement and present for the committee files a copy of the Bechtel report and then discuss with you the high points of this report so that you may see the manner in which we reach certain decisions during the consummation of this study and so that you may have some basis for evaluating the validity of the results which we are presenting.

Senator MUSKIE. Thank you very much. Your statement will be printed in the record and we will receive the report for our files.

Mr. MEREDITH. Thank you, sir.

(The statement follows:)

STATEMENT OF H. H. MEREDITH, JR., CHAIRMAN OF THE TASK FORCE ON ECONOMIC STUDY OF CARIBBEAN RESIDUAL FUEL OIL DESULFURIZATION, AMERICAN PETROLEUM INSTITUTE

I am H. H. Meredith, Jr., Coordinator of Air and Water Conservation for Humble Oil & Refining Company, Houston, Texas, and Chairman of the American Petroleum Institute's Task Force on the Economic Study of Caribbean Residual Fuel Oil Desulfurization. It is in the latter capacity that I am here today. Appearing with me as my backup is Mr. C. W. Lubbock, also with Humble, and a member of the task force who worked more closely with the contractor on highly technical problems than did the chairman. On behalf of the Institute I should like to express my appreciation for your invitation to discuss with you the state of the art in desulfurization of heavy fuel oil, a subject which has been of considerable interest to this subcommittee for many years.

You will no doubt recall that the Bechtel Corporation in 1964 made a study of costs of reducing the sulfur content of certain residual fuel oils in domestic refineries, the study being funded by the Public Health Service. Although it was an exhaustive study, it stirred considerable controversy in the refining industry, partially because some felt it did not come to grips with the realities facing the operating refiner and to some extent because it failed to deal with what many felt was the predominant problem—residual fuel oil produced in Caribbean refineries and marketed on the U.S. East Coast. Because residual fuel oils from Venezuelan crudes generally have a higher sulfur content than domestic fuel oils, as well as a higher metals content, they are more difficult to desulfurize to low levels.

In late 1965 when the American Petroleum Institute formed the Committee for Air and Water Conservation and moved into an accelerated program of conservation studies, an offer was made to the Public Health Service to conduct a second study of desulfurization funded by industry monies. This time the study would cover the Caribbean supply, East Coast demand, situation.

A recent industry-funded survey by a third party, The Pace Company of Houston, Texas, has shown that expenditures by individual petroleum companies for research on desulfurization of heavy fuel oil had exceeded $34 million since January 1946. Last year alone, these research costs exceeded $4 million. The objective of the proposed study as offered to PHS was to utilize the additional technology gained from this research, as well as to apply the know-how gained from the previous study. As PHS had been contemplating an additional study with the same objective, the API offer was accepted. API further offered to keep PHS fully informed as the study progressed and to do everything possible to include objectives proposed by PHS. As the study turned out, each of these objectives was met without difficulty and a highly beneficial study resulted, providing the most reliable answers possible with today's technology to unanswered industry and government questions. It will be the purpose of this testimony to discuss with you those facets of the study that will give you an insight into the state of the art of desulfurizing typical Caribbean heavy fuel oil.

Before the project was even defined, the American Petroleum Institute laid down two basic objectives for the study. The first was complete assurance the study would provide the guideposts needed by government bodies and agencies in order to be able to make wise decisions. The second was for the contractor to work closely with industry personnel having access to their company's research effort so latest technology would be utilized. Knowledgeable personnel were made available by the major oil companies having operations or affiliates operating in the Caribbean, or who had personnel with unusual knowledge of desulfurization processes. The task force included personnel from Cities Service, Humble, Mobil, Shell, and Texaco.

With the subcommittee's permission, I would like to proceed by quickly outlining the entire program which the task force set for itself and then come back and deal with individual parts of the procedure. In so doing I believe you will be in the best position to evaluate the validity of the data which was finally developed.

Considerable time was spent in working out the ground rules for the guidance of the contractor. Although in a sense this delayed start of the study, we found later much more time had been saved by assuring we knew where we wanted to go before we started. Next came the job of working with the contractor in selecting the typical size Caribbean refinery to be set up on the computer as a model, and selecting the major process units that would be assumed to exist in the model refinery. It was necessary, very early, to define the hypothetical product slate for the computerized model, as the selected proces units had to be capable of producing these quantities and qualities for the base case as well as the study cases. Several weeks were spent in this work before the task force and the contractor could turn their attention to investigating processes and schemes for desulfurization. Finally having determined the processes and schemes to be studied, we could turn to the task of optimizing these procedures for minimum costs, defining sizing and cost estimating the necessary additional process units, as well as the added auxiliary units that were required. Lastly, incremental operating costs were determined, giving all the building blocks necessary to ascertain the incremental costs per unit of production for various degrees of desulfurization of residual fuel oil.

Investigation revealed that 85 per cent of the residual fuel oil flowing to the East Coast came from seven Caribbean refineries. Figure 1 shows the name and location of these refineries and their capacities in barrels per stream day. This convinced the task force that no useful purpose would be served to investigate costs for more than one size of refinery, as 300,000 barrels per stream day came reasonably close to matching both the average and the typical size of those refineries producing most of the Caribbean residual fuel oil.

Figure 2 shows the crude oil charge, the process units used, and the product slate of the base case refinery. It may be difficult for the subcommittee to understand why it was necessary for the task force to determine the precise process units and their capacity in the base case model, as well as a detailed breakdown

FIGURE 1

LARGE CARIBBEAN REFINERIES

Name and Location	Crude Capacity Barrels Per Stream Day
Lago, Aruba	460,000
Shell, Curacao	280,000
Texaco, Trinidad	320,000
Creole, Venezuela (Amuay)	392,000
Shell, Venezuela (Cardon)	346,000
Mobil, Venequela (El Palito)	80,000
Gulf, Venezuela (Puerta La Cruz)	163,000
Totals, Large Refineries	2,041,000
Average for Large Refineries	292,000
Typical Large Refinery	300,000

FIGURE 2

BASE CASE

Crude Oil Charge

300,000 BPSD of 23.6° API crude oil

Process Unit Capacities	MBPSD
Crude Distillation	300
Vacuum Distillation	48
Catalytic Cracking	23
Visbreaking	72
Alkylation	2
Lube Plant	2

Yield of Saleable Products	Vol. % of Crude
Regular Gasoline	8.1
Premium Gasoline	4.1
JP-4	1.5
Jet A-1	1.5
Kerosine	4.2
No. 2 Distillate Fuel Oil	11.3
Automotive Diesel	2.6
Marine Diesel	3.3
No. 6 Fuel Oil	57.4
Lube	0.7
Naphtha	3.0
Fuel & Loss	2.3
	100.0

of the product slate. However, unless these factors are carefully established and the light products held constant through all the study cases, the computer is incapable of optimizing the desulfurization cases with the base case model. Some units were found to be common to all of the Caribbean refineries and the average size of the units was also close to the typical size. Other processes, such as vacuum distillation and alkylation, were found to be common to all refineries but had to be sized to produce a product slate of average quality and typical yields for Caribbean area refineries. After all adjustments were made and the final product slate was ground out by the computer, it was found to be typical of Caribbean area refinery production and matched almost perfectly the average yield of products from refineries in this area as reported by the Bureau of Mines.

Because of factors which I will discuss later, it was also necessary for us to designate complete quality specifications on all of the base case products. It was

here the combined knowledge of the task force was particularly valuable because several different quality specifications cannot be averaged for a product without having a completely meaningless set of values. Therefore typical, rather than average, specifications for each product was selected. I will not bore the subcommittee with the multiplicity of numbers involved. Several pages of the Bechtel report are dedicated to documentation of this information.

I would like to back up now and cover some of the major ground rules which were decided on as bases for the study. As shown by Figure 3, you will note that the crude oil gravity we selected was 23.6° API, this number being developed by the contractor as an average for Caribbean refineries. Normally we would consider this as a heavy crude oil to charge to a refinery but it is common in the Caribbean and quite typical of the mix of light and heavy crudes produced from Venezuelan oil fields. Actually this heavy material was required to give the high yields and quality characteristics typical of the heavy fuel oil produced in the Caribbean.

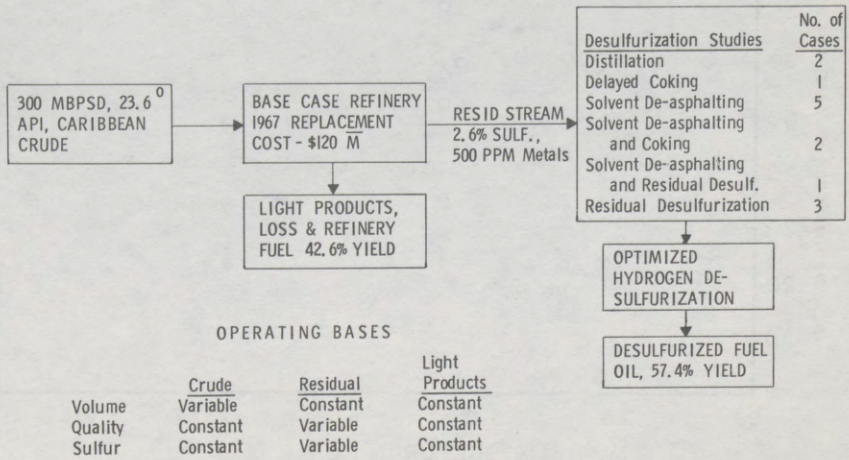
In order to duplicate the actual conditions confronting the operator of a refinery, certain additional constraints were necessary. The computer was told that it could change the volume of the crude input to the refinery but that its composition or quality had to remain unchanged. It was also told it could not change the volume or the quality of the light products as desulfurization facilities were added. This constraint was also necessary in order to reflect actual refinery operating conditions.

The residual fuel oil stream from the base case refinery has a sulfur content of about 2.6 per cent, which is average and typical for Caribbean heavy fuel oil, as is the metals content of 500 parts per million. A little better than 57 per cent of the yield from this typical refinery is residual fuel oil, which is much higher than is typical of domestic refineries. According to the latest figures available, only 8 per cent of all crude charged to domestic refineries winds up as residual fuel oil, it being more profitable to add process facilities to gain maximum yield of light products.

The computer was programmed so that the volume of the residual going to the desulfurization plant could vary but the yield of the desulfurized product had to remain 57.4 per cent. As various processes were investigated, quality was allowed to change as it was the object of the processing to lower the sulfur content and in so doing, the viscosity changed and the heating value per barrel of product also gradually decreased. Every effort was made by the contractor to hold viscosity up because you will recall there is a lower limit of viscosity for importable heavy fuel oil.

Fourteen desulfurization schemes were investigated, utilizing six different processes or combination of processes. The task force did not control the contractor's selection of processes to be investigated. He was given the latitude of utilizing any process which in his opinion was commercially proven and on which he could obtain process information from the licensor. Companies repre-

FIGURE 3



1-57-25

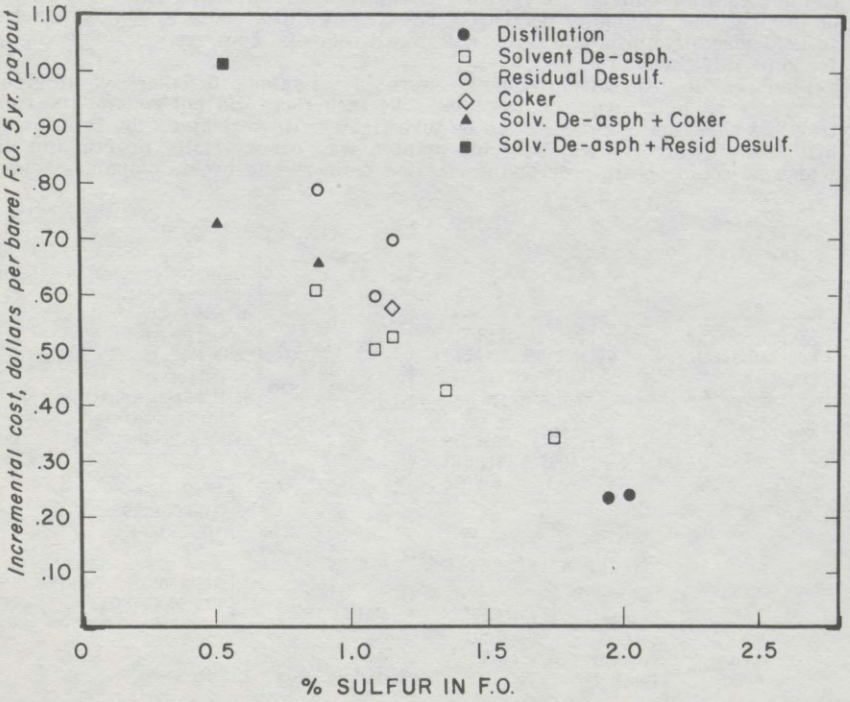
sented on the task force also submitted confidential information we could not, for competitive reasons, share with each other. I stress this point because I am aware this subcommittee has been concerned with the apparent manner in which the competitive nature of the oil industry has sometimes seemed to hamper sharing of research information. In conducting this study no such difficulty was encountered, although there were many occasions on which we freely admitted to each other that we had information we would furnish to the contractor direct but which we could not divulge to the full task force. This will also serve to explain why no one on the task force can discuss precise operating details of the various desulfurization processes; nor can any of us take the Bechtel report and construct any but the simplest of the desulfurization facilities investigated without further access to the confidential and proprietary information known only by the contractor and by the licensors.

Before leaving this part of the study it should be pointed out that for shallow desulfurization a straight distillation process was used. Delayed coking, solvent deasphalting, and whole resid desulfurization were processes utilized for intermediate depths of desulfurization; whereas solvent deasphalting *plus* coking or *plus* residual desulfurization were used for the most intensive processing. All cases, it should be noted, utilized optimized hydrogen desulfurization of streams subject to such treatment and all cases included facilities for recovering the sulfur removed from the oil.

The 1967 replacement cost of $120 million for the base case refinery should be noted for later comparison with added investments for desulfurization facilities.

Figure 4 presents in graphic form all the per barrel costs that were developed from the desulfurization studies. There are certain factors which I would like to present for your consideration before you begin to interpret this data. First of all, I would stress that these costs were developed from *incremental* investment and *incremental* operating costs. The investments were determined by the contractor from his experience in the Caribbean and from his discussions with licensors. The additional costs required to operate the desulfurization facilities

FIGURE 4



were developed from contractor experience and by discussions with operating companies. They actually represent a blend of Venezuelan and island type operations. All costs, however, are on a "before-tax" basis.

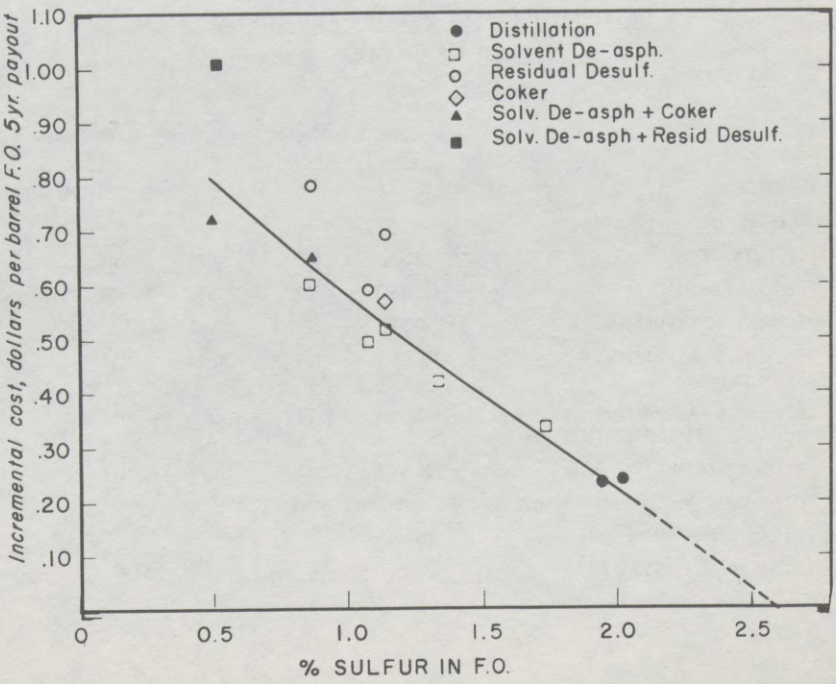
You have no doubt heard much discussion of the effects of recovered sulfur on the overall cost of desulfurization. The task force instructed the contractor to value the recovered sulfur at $32 a long ton, which on today's market is a reasonable price. However, we wished to determine how sensitive fuel oil desulfurization costs would be to changes in the market price of sulfur. To determine this sensitivity the market value of the sulfur was arbitrarily increased by $5 per long ton above market price and then $5 below market price, with all other conditions held constant. The sulfur credits thus obtained were found to change the net cost of desulfurization by about 2¢ per barrel. In any of the desulfurization cases the total credit for recovered sulfur amounted to less than 9¢ per barrel. In comparison with desulfurization costs we are likely to encounter, sulfur credits are quite small.

The study assumed the additional facilities required for desulfurization would be built with 6 per cent borrowed capital and a ten-year depreciation rate was used. The cost presented on Figure 4 and subsequent charts are all keyed to a five-year payout. Tables in the report show three other sets of costs, one a zero profit case, or a ten-year payout; one, a three-year payout; and one, a 1½-year payout. The information is presented so that sensitivity to payout can be determined. The five-year payout basis seems to be reasonable in this high investment, high risk situation.

If we take the case of solvent deasphalting, which reduced the sulfur level of the fuel oil to 1.09 per cent, you will note Figure 4 shows a cost of 50¢ per barrel. This is made up of a incremental operating cost of 16¢ and an allowance for a five-year payout on the investment of 34¢. Had the cost been based on a ten-year payout the total cost—including operating expenses—would have been 32¢. Had it been on the basis of a three-year payout the total cost would have been 73¢; and on the basis of a 1½-year payout, $1.31.

By now, I would presume you have mentally drawn in a curve on this figure to determine likely costs for high degrees of desulfurization, but this is a difficult task unless one has a good feel for the reliability of the points. Figure 5

FIGURE 5



shows the curve of costs drawn by the contractor to represent the most likely cost for any intensity of desulfurization. There are two reasons the curve was not a straight line through the five lowest points and also why the curve begins to bend upward below 1 per cent sulfur in the fuel oil. The solvent deasphalting case with delayed coking, which gives a very attractive cost at the 0.5 per cent sulfur level, does not represent a finished case. This process produced a 746 ton mountain of coke each day for which we could find no use and the cost does not include an allowance for disposition of this vast quantity of unusuable material.

You will note all of the low points involve solvent deasphalting. While this process has been commercially proven on the domestic stocks there have been no commercial demonstrations on stocks with the high metal content typical of Caribbean crudes. These factors cast enough doubt on the validity of the lowest cost cases to justify a faired curve through the points. What is not apparent from the curve, which seems to carry more authority than it really does, is that we do not have as much confidence in the data below about 0.87 per cent sulfur as we do above this sulfur level. Below this point catalytic treatment of process streams is required and we can only guess at the metal content of these streams and the resulting catalyst life.

Metals in a process stream tend to deposit on the surface of the catalyst and as a result, deactivate it. If our estimates turn out to be inaccurate, the costs shown for the lower sulfur content resids will be in error. I can only say at this point that if the timing of regulation requires the industry to attempt to achieve levels of desulfurization at the upper end of this curve, the oil industry will be forced to be a party to one of the biggest gambles in the history of the business because we cannot determine without pilot plant work and many months of time which present schedules will not allow, to pilot plant these processes and determine if our estimated values are correct. I would also say to the subcommittee at this point this report is silent on feasibility of processing and the costs involved in reducing sulfur content below 0.5 per cent. We are already pretty much in the dark as to the validity of the numbers at this point and it is not without intention that we have avoided extrapolating our ignorance. Other factors are involved also.

Figure 6 presents a tabulation of the lowest level of sulfur content achieved by the best of each of the process schemes. Please note the rather startling

FIGURE 6

RESIDUAL PRODUCT QUALITY AND COSTS

(LOWEST SULFUR CASES)

	Sulfur Wt. %	Viscosity (3)	Metals PPM	Inc. Cost $/B(2)	Inc. Invest M $
BASE CASE	2.6	170 SSF	500	-	120 (1967 Replacement Cost)
PROCESSES (1)					
DISTILLATION	1.96	88 SSF	478	0.24	44
DELAYED COKING	1.14	145 SSU	265	0.58	88
SOLVENT DE-ASPHALTING	0.87	220 SSU	275	0.61	100
SOLVENT DE-ASPHALTING AND COKING	0.5	145 SSU	189	0.73	118
SOLVENT DE-ASPHALTING AND RESIDUAL DESULFURIZATION	0.52	145 SSU	23	1.02	154
RESIDUAL DESULFURIZATION	0.87	210 SSU	342	0.79	117

(1) All cases include optimized hydrogen desulfurization processing

(2) 5 yr. payout before taxes

(3) SSF @ 122^0 F; SSU @ 100^0 F

1-57-43

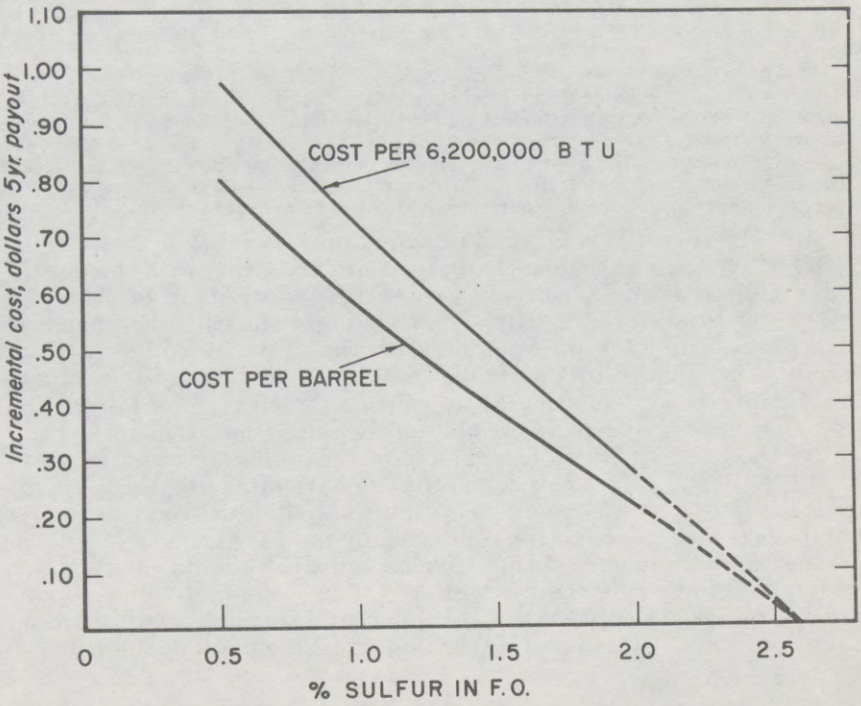
changes which take place in viscosity. I will discuss the significance of these changes a little later. Note also the reduction in metal content. Although as I have stated, some of these numbers are educated guesses, the numerical value is extremely important in the eyes of many authorities on air pollution. Metals in the fuel generally wind up as metals in the atmosphere so that those with whom we worked in PHS on this study were very pleased to see the rather significant reduction in metals that came as a side effect of desulfurization.

Calculated values of incremental costs per barrel are presented in the next to the last column. These correspond to the plotted points on Figure 5, not to values read off the curve. The column on the far right shows the incremental investment required for each of the processing schemes. Even those of us who had followed this study as it developed were startled at the magnitude of these numbers. It can be seen we are dealing with major investments, some of them exceeding the 1967 replacement cost of the base case refinery. I wish to make this point crystal clear. If intense desulfurization of Caribbean fuel oil becomes a requirement, owners of Caribbean refineries will be faced with building facilities either in the Carribbean or at some other location that will equal in size, complexity and cost, the total facilities they now have.

The column on viscosity tells more than meets the eye. A lower viscosity number generally means a lower density of the material and a lower heating value for each unit volume of the material. Although for convenience a purchaser buys heavy fuel oil by the barrel, he is really purchasing BTUs, or that is to say, heatting units, so that he has to consider the heat per barrel in determining his actual costs for generating heat or steam.

Figure 7 shows the actual additional cost to fuel users as a result of the reduced heating value of the desulfurized fuel oil. The lower curve is identical to the one shown on Figure 5; whereas the upper curve shows costs based on 6,200,000 British Thermal Units, the heating value of a barrel of normal residual fuel. It is difficult to read precise value from these curves, but three points would seem to be of particular interest to this subcommittee.

FIGURE 7



You may recall that API presented information on desulfurization costs in June 1965 when the Bureau of the Budget and the President's Office of Science and Technology were studying draft regulations applying to federal installations. Our testimony contained statements to the effect that the state of the art at that time was such that a maximum of 30 per cent reduction in sulfur content of typical Caribbean heavy fuel oil could be achieved and the cost would be about 40¢ per barrel. Although since that time the state of the art has advanced so that more intense desulfurization is possible, it is interesting to note that for a 30 per cent reduction from 2.68 weight % (1.82 per cent sulfur in the desulfurized product), the Bechtel study shows a cost of about 30¢ per barrel, or about 37¢ on a constant BTU basis. The 1 per cent point is also of interest because of our confidence in the data down to the level. Here it would appear the costs will be about 58¢ per barrel or about 72¢ on a constant BTU basis. Although we do not have the same degree of confidence in the costs at the 0.5 per cent level, our best estimate is that costs will be about 80¢ per barrel, or about 97¢ per equivalent barrel of heating units.

With the subcommittee's permission, I would like to present a copy of the Bechtel report to Committee files, and I would conclude this presentation with a summary of what this report says and what it does *not* say.

First it says typical Caribbean residual for oil containing about 2.68 per cent sulfur by weight can be desulfurized, but not without some penalties in lowered viscosity and in lowered heating value.

The report stresses that limited process information is available on feedstocks with the high metal contents typical of Caribbean crude oils.

When the sulfur content is reduced to about 1 per cent, the viscosity of the oil is reduced to the lowest limit of ASTM specifications for No. 6 fuel oil (45° SSF at 122° F.).

When the sulfur content is reduced to 0.5 per cent the viscosity reaches the lowest limit allowed by import regulations (145 SSU at 100° F.).

The incremental cost to reduce sulfur content to 1 per cent is about 72¢ to produce fuel with the equivalent heating value of a barrel of today's average Caribbean residual fuel oil.

On a similar basis the cost to reduce sulfur content to 0.5 per cent is about 97¢. (To put these incremental costs into a frame of reference, the cost of No. 6 fuel oil according to Platt's OILGRAM Price Service, low posting, no sulfur guarantee, FOB barge, New York Harbor on May 10, 1967 was $2.28 per barrel.)

Finally, the report says that investment required to build the facilities to achieve a high degree of desulfurization would roughly equal the 1967 replacement cost of the existing Caribbean refineries. This could mean total investments in excess of three-quarters of a *billion* dollars.

I wish to express the appreciation of the Institute for allowing us to present the results of the Bechtel study to this subcommittee and to express my own personal appreciation for the courtesies which you have extended.

Mr. MEREDITH. I would like to express my own belief that this report will become a benchmark of excellence in dealing with this particular subject. I think there are two reasons why this is so. First, we were able to work out a satisfactory arrangement with the same contractor who did the previous desulfurization of fuel oil study, this study being funded by the Public Health Service. Thus, we were able to utilize the accumulation of knowledge that was gained from this previous report. We also were able, at the same time, to gain the benefit of the research which has gone on within industry over the years.

In testimony before this committee we have often alluded to the research effort that was going on within the individual companies over and above the research being conducted by industry groups such as the American Petroleum Institute. Concurrent with our study an API survey was being conducted by the Pace Co. in which individual companies were asked to give to this third party on a confidential basis their research costs, both on desulfurization of all fuels and on desulfuriza-

tion of residual fuel. This report has not become available yet but it will show that some $34 million had been spent by individual oil companies and related research companies since 1946 on desulfurization of residual fuel. In the year 1966, $4 million was spent for this same purpose.

Our task force was constituted of personnel from companies having affiliates in the Caribbean or who had operations directly in the Caribbean. One of the ground rules for appointment to this committee was that the member should have access to his company's research effort so that he would be able to supply this knowledge or this information to the contractor.

Here again as in the Pace study we were able to overcome the competitive aspect of our business which keeps us from sharing our research secrets with each other. We were able to feed directly to the contractor on a confidential basis much information which we could not share with each other; he was able to ut'lize it and to benefit from it, and we were able to maintain our competitive position.

A third point which I wish to stress, and which also makes this study extremely significant, is that it was carried out in complete cooperation with the Public Health Service. From its very inception the Public Health Service was involved. We went to them originally and said in net effect, "You have conducted a very fine study. We feel if there is any lack in the previous study it was that somehow we did not give you the benefit of our industrial knowledge on this subject. We really, as we consider it now, feel that it is our responsibility to make this study for you and we want this study to give to you and to other governmental bodies those guideposts which are necessary for you in making wise decisions. Therefore, we offer to make this study, as we know you have been thinking about making such a study," which they confirmed.

The offer was accepted by the Public Health Service, and we have kept them informed of each step. We have asked for their advice; they have freely given it. It has been a very satisfactory relationship between a governmental agency and an industrial group working on a problem of considerable interest to this subcommittee and also a matter of considerable public interest.

One can hardly understand the basis of this report without a comprehension that the Caribbean refinery is an entirely different animal from the domestic refinery.

Here in the United States we find it more profitable to install process equipment which will achieve maximum yield of light products. Therefore the average yield of residual fuel oil from all refineries in the United States is 8 percent of the total products.

Senator MUSKIE. That percentage has declined over a period of years, has it not?

Mr. MEREDITH. Yes; it has declined considerably, something like 50 percent in the last 10 years.

On the other hand, the Caribbean refinery is what we would call, in domestic operations, more of a skimming refinery in which the processes are rather simple, in which the light products are only a relatively small portion of the total and in which the residual fuel is one of the major products. About 57 percent of the total yield of the Caribbean refinery is residual fuel.

77-515 O—67—pt. 4——18

We had some difficulties that did not confront those who made the previous study on domestic residual; we had some things which were rather simple in comparison also. Whereas the previous study considered several types of refineries, and several sizes of refineries, one of the first things that came to us as a result of investigation by the contractor was that 85 percent of the residual fuel oil flowing to the east coast of the United States originated in the seven refineries which are shown on the chart to your right (fig. 1).

It will be noted that the average of the capacity of these refineries, 292,000 barrels a day, is very close to the typical size of these refineries. So it was the conclusion of the committee that it would be necessary to study only one size of refinery and this considerably simplified our work.

In the setting up of a model for a refinery, it is very important that the units be sized so that they will in actuality produce the crude slate. The next chart (fig. 2) will show you what our model Caribbean refinery looks like in terms of the units which are involved. The small number of process units is listed at the upper part of the chart. The chart also shows you the products which are produced from this refinery. I will not bore you with the details. The numbers which should stand out to you are the relatively small size of regular gasoline, premium gasoline, and jet fuels, in terms of percentage of the total yield and the 57.4-percent yield of residual fuel.

Each and every one of these products as far as the mathematical model is concerned, must have a certain quality specifications. Now this was a place in which the refining experience of the members of the committee put us in good stead, because one cannot average specifications and come out with anything more than a meaningless jumble of numbers. So it was necessary for us to go through and select what would be a good typical specification for this mathematical model to produce on each one of the light products as well as the residual fuel.

The product slate shown matched almost exactly the average of the Bureau of Mines percentage data for the total of all Caribbean refineries; and the size and the identity of the processing units were also very close to the average and the typical size of such units in Caribbean refineries.

Figure 3 will help to show you the problem areas which we had confronting us as we began our study, the first being the base case refinery, which accepted the crude (23.6° API) which is typical of the Caribbean; a rather heavy crude, if you will, in terms of what would be processed in a domestic refinery, but a crude which is necessary, and required as a matter of fact, to produce the product slate of this refinery. Three hundred thousand barrels per day are shown coming to the refinery.

There were certain constraints which it was necessary to put on this refinery as far as a mathematical model was concerned.

We told the contractor to tell the computer it could change the volume of the incoming crude, but its quality could not be changed because this is the problem which confronts the actual refiner in the Caribbean. We cannot change composition of his crude. He can change his volume but that is about all.

We told the contractor to instruct computer also that as far as the light products were concerned, their volume and quality had to be held constant no matter what we did on the additional facilities required to desulfurize the residual fuel. This again reflects the actual operating conditions confronting a refiner.

As far as the residual fuel oil was concerned, we found that a typical fuel oil and the average quality of fuel oil flowing from the Caribbean was about 2.68 weight percent sulfur and 500 parts per million of metals. Now I don't know if the parts per million will mean much to you. Suffice it to say, this is an extremely high metal content for a residual fuel.

We put some constraint on the residual fuel. As the processes were investigated we had to let the quality of the residual fuel oil change, unlike the light products. It had to be allowed to change because as we process a heavy material the common tendency is for it to become thinner, and despite everything we could do, the viscosity did change rather drastically as the intensity of processing increased. The heating value of this material per barrel changed also as viscosity and gravity changed.

Now, on the right hand side of figure 3, we simply list for your consideration the fact that there were 14 processes, or combinations of processes, which were investigated by the contractor. We told him that we would not put any constraints upon him as to the processes which he felt were worthy of investigation other than to state that it should be a commercial process although we did not tell him how to arrive at this conclusion.

So the contractor, in whom we developed a great deal of confidence, assured us that he found that each one of these process which was investigated was a commercially feasible process. Only in one place, as I will discuss with you in just a moment, did he, and we, feel like there was some qualification to this particular point.

We told him as far as his source of information was concerned, that we, and member companies of the committee would make available to him any information which we had and which he felt that he needed from us. Some of the companies represented do have licensed or proprietary type of processes which were made available. We told him that he could go to any other source of proprietary information where he could work out a satisfactory arrangement with the licensor. And he did go to each and every source of information, supplementing information which he had, in order to give the results we are presenting today of the feasibility and the degree of desulfurization and the costs which were involved in running each one of these processes to the ultimate of its capability.

I should point out that no matter how simple the process, there was an optimized hydrogen treatment shown in the middle box on the right hand side, involving the conversion of sulfur in the residual fuel oil to hydrogen sulfide under pressure and in the presence of a catalyst. Each and every process did involve this step.

Now, on figure 4 are shown the per barrel costs developed from all of the desulfurization studies.

Before you begin to interpret this data I would like to give you some factors to consider so that you will understand what the plotted values

actually mean. All of the cost information was developed from incremental investments and from incremental operating costs over and above the base case refinery which is assumed to exist in the Caribbean area.

The investments came from the contractor's experience in the Caribbean and from discussions with the licensors. The operating costs came also from the contractor's experience and from our counseling with him on our experiences, giving him the benefit of our operations in the Caribbean. Actually, these operating costs turned out to be a blend of Venezuelan and island type operations which are rather different in their nature.

I cannot stress too much the fact that all these costs are on a before-tax basis or without a tax basis, if I may coin a phrase. Taxes are not involved here, this being a rather complex situation in the Caribbean and one which would tend to mask the information which we are presenting, with information which would not contribute to our objective.

I know you will be interested in sulfur credits. Much has been said about the ability of desulfurization processes to be sustained by the byproduct sulfur credits. We assumed in this study, and it has turned out to be a good supposition, that sulfur was worth $32 a ton; but in order to evaluate for you and for us the sensitivity of the desulfurization cost to differences which might occur in the price of sulfur, we had the computer change the price of sulfur up $5 above the market price and then down $5 below the market price. We found the effect of this change on the cost of desulfurization was 2 cents per barrel.

Another benchmark which will be meaningful to you will be the cases in which considerable sulfur was removed, as much as 469 tons per day. In this case credit to the process was 9 cents per barrel, so you can see we do not get an appreciable reduction in processing costs by virtue of the sulfur credits.

Payout of the invested capital is keyed to 6 percent borrowed money and a 10-year depreciation rate. This is extremely important because the investments are considerable and the costs are quite sensitive to the rate at which the investor feels he must recover his capital.

We considered a 10-year payout plan which is a no-profit affair. You simply end up at the end of 10 years with your equipment depreciated out and you have your money back and you find that you have made no money. We considered a 5-year payout, equivalent to about a 10 percent rate of return, a 3-year payout, and a 1½ year payout.

We might explain to you how these payouts affect the total cost, by taking the single point on figure 4 where we had solvent deasphalting which reduced the sulfur content to about 1.09 percent at a total incremental cost of 50 cents per barrel. The operating labor, maintenance, supplies, all of the out-of-pocket costs amounted to 16 cents out of this 50 cents, and the remaining 34 cents was cost which had to be charged to recovering the invested capital in 5 years' time.

Now had the payout been on the basis of 10 years (no profit situation) the total cost to compare with the 50 cents would have been

32 cents. So there is not a large difference between the no profit case and what we would consider to be the reasonable profit case.

However, if one shifts to a 3-year payout (recovers capital in 3 years), the total cost would have been 73 cents per barrel and had we considered that it was necessary to recover the capital in a year and a half, the total cost would have been $1.31 per barrel.

Now these are all the points developed while producing the study. I am sure you have drawn your own mental curve through these points. Figure 5 shows you how the contractor, with his knowledge of the validity of the information, drew his curve.

Although many of us would have disagreed with him as to whether or not his curve represented the best interpretation of the data, we did not change his original drawing of that curve. You will note that the curve is not through the low points on the chart. Had it been drawn through those low points, it would have been a straight line going to zero sulfur at something like 90 cents and we know that is not a correct conclusion to reach.

All of the low points you will note from the legend are processes utilizing solvent deasphalting. Now while solvent deasphalting is a commercially developed process and has been proven on domestic stocks, it has not been commercially demonstrated on stocks having the high metals content of the Caribbean residuals.

The very attractive looking point at 0.5 percent sulfur involving solvent deasphalting for a cost of a little more than 70 cents needs some comment. This process produced a 746 ton-per-day mountain of coke for which we could find no use; so we consider that as an unfinished case and not having in it costs which would be necessary to dispose of this rather voluminous amount of coke.

Three points on the curve would seem to be of particular interest to this subcommittee. When the Bureau of the Budget and the President's Office of Science and Technology was investigating draft proposals of the regulation for Federal installation, the American Petroleum Institute testified, and that was in the middle of 1965, that the extent of our technology at that time was such as to make it possible to reduce sulfur content of residual fuel oil by only 30 percent and the cost would be about 40 cents per barrel. Here we are, something like 2 years later, our degree of expertise has increased appreciably, and much higher degrees of desulfurization are within our capability now. So we go back to look at that 30 percent point which, starting from 2.68 percent, would be 1.82 percent and we find, reading from this curve, that our cost would be something on the order of 30 cents per barrel. At 1 percent, a much talked about point, the cost would be 58 cents per barrel on this curve and, at the 0.5 percent point it would cost, according to this curve, 80 cents per barrel.

Now going to figure 6, briefly, let me go over this chart which presents the high points of the study. These are the lowest level, best process schemes which are delineated. You will note the base case gives us 2.6 weight cent sulfur. The viscosity numbers need some elaboration. They mean something to us in the business but you have not any feel

for the vast changes in the viscosity unless we tell you that if the 170 SSF could have been stated on the other basis (SSU), it would have been something on the order of 2,500 to 3,000. So you see there has been a vast change in the viscosity.

As far as the metals contents are concerned, there is more here than meets the eye. We started with 500 parts per million of metals in the base case. The report delineates what those metals are. There were, in some of the processes, considerable reductions in the metal content, the solvent deasphalting winding up with an estimated content of 23 parts per million. This is considered to be particularly important in the eyes of some authorities and particularly the Public Health Service in which it is rightfully concluded that metals in fuel will wind up as metals in the atmosphere. They were extremely pleased to see the reduction in metals content which was a byproduct of the desulfurization process.

Generally the lower viscosity numbers mean a lower density and a lower heating value per barrel of fuel. I will show you what this means to us in a moment. The most important column to us who are faced with the prospect of making investments in the Caribbean, or at some other place, for the desulfurization of Caribbean residual fuel oils is the column on the far right. You will note that the contractor gave us a number of 120 million as the 1967 replacement cost of the base case refinery that we studied. In comparison with that, we have some of the processes requiring as much as $154 million incremental investment, over and above the equipment which is on hand at the present time.

These are tremendously large investments. They mean to those of us that conduct operations in the Caribbean that either there, or at some other place, we would in net effect have to build again, all of our refineries which are existing in the Caribbean, if we followed the procedures outlined in this particular report.

Figure 7 shows that inasmuch as there is a change in the British thermal unit content of a given volume of material as its viscosity changes, we have to spell out to the consumer what his costs will be on a constant British thermal unit basis because in generating steam or electricity he is not buying barrels of material so much as he is buying heating units: 6.2 million British thermal unit, the report uses 6.3 million, is the content of a barrel of normal viscosity residual fuel. So when we put costs on a constant British thermal unit basis we get costs to the consumer which are somewhat above the per barrel cost. As a result we find that we have to interpret this, in terms of incremental desulfurization costs, as the cost for equivalent British thermal unit.

We have, in comparison with the three other points which we read to you from the other curve, the 30-percent reduction point or 1.82 percent sulfur, 30 cents per barrel for the per barrel basis compared to 37 cents vertically above that point for the cost on a constant British thermal unit basis. At the 1-percent point, 58 cents per barrel has gone to 72 cents per equivalent barrel and the 0.5-percent point goes from 80 cents to 97 cents on an equivalent British thermal unit basis.

I would offer one word of caution. In looking at the upper part of the curve, I can only say, that the fact that we have not actually

deasphalted residuals with this high metal content gives us some feeling of insecurity about the data below 1 percent, below 0.87 percent to be precise. It is at this point that processes come into play which utilize catalysts which could be rather drastically poisoned by the metals content. So we had very little better than educated guesses as to what the catalyst life would be with this high metal content residual. Therefore, we do not have the same feeling of confidence below that point that we do at sulfur contents above that point.

Let me close now was a summary of what this report says and what it does not say.

First, it says that typical Caribbean residual fuel oil containing about 2.68 percent sulfur by weight can be desulfurized but not without some penalties in lowered viscosity and in lowered heating value.

The report stresses that limited process information is available on feedstocks with the high metal contents typical of Caribbean crude oils.

When the sulfur content is reduced to about 1 percent, the viscosity of the oil is reduced to the lowest limit of ASTM specifications for No. 6 fuel oil. This is 45 SSF at 122°. When the sulfur content is reduced to 0.5 percent the viscosity reaches the lowest limit allowed by import regulations; namely, the lower limits of Navy Special, or 145 SSU at 100° F.

The incremental cost to reduce sulfur content to 1 percent is about 72 cents to produce fuel with the equivalent heating value of a barrel of today's average Caribbean residual fuel oil. On a similar basis the cost to reduce sulfur content 0.5 percent is about 97 cents.

Now to put these incremental costs into a frame of reference which will be meaningful to you, the cost of No. 6 fuel oil according to Platt's Oilgram Price Service, low posting, no sulfur guarantee, free on board barge, New York Harbor on May 10, 1967, was $2.28 per barrel.

Finally, the report says that investment required to build the facilities to achieve a high degree of desulfurization would roughly equal the 1967 replacement cost of the existing Caribbean refineries. This could mean total investments in excess of three-quarters of a billion dollars.

I wish to express the appreciation of the Institute for allowing us to present the results of the Bechtel study to this subcommittee and to express my own personal appreciation for the courtesies which you have extended.

Senator MUSKIE. Thank you, Mr. Meredith. You have undertaken a formidable task to educate me, a layman, on technicalities of this problem, but I think you have succeeded at least to the point where I think I understand the conclusions that you have just stated and the implications in terms of costs and policies. So with that I thank you for your presentation and for the submission of your report.

Mr. MEREDITH. Thank you, sir.

Senator MUSKIE. Now we have one remaining witness. We have gone through the noon hour. I hope you are all going with me. I think that in light of my schedule I ought to get the hearing concluded.

Our next witness, Mr. Sherman K. Reed, director of Central Research Department of the FMC Corp.

STATEMENT OF SHERMAN K. REED, DIRECTOR, CENTRAL RESEARCH DEPARTMENT, FMC CORP., ACCOMPANIED BY NORRIS J. BRUNSVOLD, FMC CORP., PRINCETON, N.J.

Mr. REED. Thank you.

Mr. Chairman, I have with me Mr. Norris J. Brunsvold, also of FMC Corp.

We have submitted a statement, which I believe you have, from our organization. I would like that included in the record.

Senator MUSKIE. It will be placed in the record in its entirety.

(The statement follows:)

PREPARED STATEMENT OF SHERMAN K. REED, DIRECTOR, CENTRAL RESEARCH DEPARTMENT FMC CORP., PRINCETON, N.J.

My name is Sherman K. Reed. I am Director of the Central Research Department of FMC Corporation. FMC owns and operates chemicals, fibers, machinery, and ordnance plants throughout the United States and abroad. My purpose in appearing before you today is to present technical and economic information concerning a process under development by FMC Corporation which has the poential of reducing air pollution by sulfur dioxide.

FMC, for a number of years, has been deeply interested in the processing of coal and has made a major investment in the development of certain processes which permit low-grade coals to be upgraded for coking purposes. In the course of that work, FMC developed a considerable skill in what is known as the fluidized-bed pyrolysis process. As a result of this experience, in 1962 FMC Corporation entered into a contract with the Department of Interior, Office of Coal Research to develop a comparable process for converting coal to the more valuable products, synthetic crude oil, pipeline gas, and a solid fuel char. The oil and gas produced by this process are sulfur-free, but the char, had a sulfur content similar to the starting coal. That work, known as Project COED, which stands for Char Oil Energy Development has been going on continuously since 1962. It is now ready to enter the pilot plant phase.

In the course of this development work, FMC recognized that the process might permit the economic addition of a char desulfurization step. We discovered that sulfur can be removed from the char with by-product hydrogen from the COED process. The cost is low because the char comes out of the process at just the right temperature for sulfur removal. From the experiments FMC has conducted, we believe this process is one of the most atractive research and development projects to pursue to obtain a low sulfur fuel economically. Such a char could be used in major electrical power generating plants located in metropolitan areas without significantly adding to the sulfur oxide content of the atmosphere.

You may be interested to know that even before some of our more recent research work, this projects was reviewed for the Department of Interior by the Blaw-Knox Company to give an independent appraisal of its potential. Without going into all the details, the Blaw-Knox report makes clear that the COED project, as a whole, shows substantial commercial promise and fully justifies the next step in the program which is the pilot plant phase. Among the comments made by Blaw-Knox which are of most specific interest to this committee is the following:

"As FMC has realized, another promising use for the 'by-product' hydrogen could be sulfur removal from char, based on the laboratory work they have begun for char hydrodesulfurization. Low-sulfur char could qualify as a premium fuel."

Where do we stand today? Working with char from Illinois No. 6-seam coal, we have repeatedly demonstrated the ability to reduce the sulfur level in the char from over 3 percent to as low as 0.3 percent. Char from the process, at 1600°F., and hydrogen from the COED-produced gas are passed into a reactor. The sulfur is removed from the char and later recovered as pure sulfur. The low-sulfur char is cooled and available for use. In our tests we have used the

char from the Illinois No. 6-seam coal as a typical high-sulfur char. Most of the Mid-Western and Appalachian coals going into boilers today are high-sulfur coals. We anticipate that this same technology being developed will be applicable to chars produced from any of these coals by the COED process.

I believe it would be helpful to you to have a more complete picture of the economics of this entire process. Our economic projections are based upon a commercial plant which processes 10,000 tons of coal per day. For a 10,000-ton plant, the char yield will be approximately 5,000 tons per day, the balance being an oil, gas, and other products. The char produced may have slightly less energy than an equivalent quantity of coal, and our estimates take this into account. For every $100 worth of coal put into the process, the process cost exclusive of desulfurization will be $70. The oil, synthetic gas, and char produced will have a market value of approximately $245. Thus, on its face, apart from the desulfurization aspect, the project shows great promise of commercial feasibility. Again I might add that our evaluation has been confirmed by independent reviews.

Now let me turn to the economic of the desulfurization process. The desulfurization process will have a net cost of approximately 10¢ per ton of char. This allows 60¢ credit for sulfur at today's price. Even if we took the lowest market price for sulfur since 1957, the total net cost would be only 30¢ per ton.

Where do we go from here? Working under the current contract signed last September with the Office of Coal Research, we are nearing the end of the design stage of a COED process pilot plant. Unfortunately, funds for the pilot plant which can commence in July 1967 were not included in the 1968 budget for the Department of the Interior. We are hopeful that Congress will appropriate the funds to pilot this process and understand that this may be under consideration before the Senate Appropriations Committee. Assuming that funds are made available, and while the pilot plant is being constructed, we plan to advance our desulfurization technology and incorporate the desulfurization step in the pilot plant. Because the estimated return on investment of this process is sufficiently attractive to private industry, we foresee the construction of the first commercial COED plant beginning in 1970. Thus, a first commercial COED plant producing low sulfur char for power house fuel could become a reality by 1972. Some acceleration of this schedule is possible based upon funding.

We believe that Project COED holds great promise of increasing the use of the nation's coal reserves and for substantially increasing employment in the coal-producing areas. Because the capital cost of such a plant is relatively low compared to the value of the products it produces, it may be widely utilized and private investment will be encouraged.

I want to thank the Committee for hearing me today. I believe that this Committee is performing a valuable service to the Nation in making apparent the importance of technological advances in solving our air pollution problems.

I believe that Project COED can not only increase the use of coal but will also aid significantly in reducing air pollution.

Mr. REED. Considering the time, I will summarize what is in here and not read the statement, and then I will be happy to answer any questions you may have relative to it.

FMC Corp. is a major chemical, fiber, machinery, and ordnance corporation. My purpose here is to tell you about some research that we have been carrying out in cooperation with the Office of Coal Research which we believe has the potential of having considerable impact on solution of the pollution program problems in the future.

As to background, FMC Corp. has been carrying out research in the area of fluidized-bed technology for approximately 12 years. In early 1960 the Office of Coal Research approached us to carry out a research process they called Project COED. This involves treatment of coal by procedures in which we were skilled to produce an oil, a char, and a gasoline.

As originally conceived, it was expected that the char that was produced would have the sulfur content equivalent to the coal. However,

as time went on we recognized that hydrogen is produced as a byproduct with this process so a potential was offered that this hydrogen might be utilized to remove sulfur from the char.

Looking at the economics of the COED process we considered a 10,000-ton-per-day plant which involves the use of 3.5 million tons of coal per year. Under these circumstances if one considers feeding a hundred dollars worth of coal to the plant approximately $70 worth of processing cost would be involved. Two hundred and forty-five dollars of product are produced. This is the oil, the gas, and the char.

The oil is sulfur free even though a sulfur-containing coal is used. The char as originally conceived contained sulfur. Blaw-Knox, an engineering organization, was contacted, and given the task by the Government to evaluate this process to see whether it had technical and economic feasibility and whether or not a contract should be given to FMC to pilot plant this process.

Their evaluation in this report was that the analysis of FMC is, if anything, conservative and that the process appears to hold substantial commercial promise.

In particular, however, they noted as follows, and I will read briefly the quotation because I think it is important:

> As FMC has realized, another promising use of the "byproduct" hydrogen could be sulfur removal from char, based on the laboratory work they have begun for char hydrodesulfurization. Low-sulfur char could qualify as a premium fuel.

Since that time we have done extensive laboratory work on char available from our process development unit and have demonstrated that it is possible to remove 90 percent of the sulfur from a char which originally contained 3 percent sulfur, thus the remaining sulfur is three-tenths of a percent.

The cost associated with this, allowing a credit for the sulfur which can be recovered as pure sulfur by presently available technology, the costs are 10 cents per ton of char. This takes into account a 60-cent sulfur credit; thus the whole cost without sulfur credit is 70 cents per ton of char.

At the present time we have a contract with the Office of Coal Research signed in September of 1966 to build and operate a pilot plant. This work has been funded through fiscal 1967. Unfortunately, funds were deleted from fiscal 1968 although at the present time the Senate Appropriations Committee is considering reinstating funds to carry forward this program.

What could this process yield? If the pilot plant is constructed on schedule, we visualize the work will be complete in 1969, and would be possible to begin construction of a commercial plant in 1970 to be completed in 1972. This would yield a char which we believe would be a product which will hold promise as a premium fuel although our economics, which is attractive, is based upon its being sold at below the cost of the fuel value of the coal that goes into the process. We feel that Project COED of the Office of Coal Research will accomplish the objectives which are to increase employment, to increase the utilization of coal and at the same time holds the potential bonus of producing a fuel that is low in sulfur and can be effective in abating air pollution.

I would like to thank you for the opportunity to briefly summarize this and also to appear before you and submit the statement.

I will be happy to answer any questions.

Senator MUSKIE. Well, I don't have as many questions now as I might have had before, but I do have two or three.

What is the B.t.u. loss from coal to char?

Mr. REED. Well, originally almost 2 tons of coal are required for every ton of produced char. This extra ton appears as oil and gas from which you can recover B.t.u. values. The char itself is between 5 and 10 percent less B.t.u.'s per pound of char as compared with the original coal.

Senator MUSKIE. Can the char be used in presently installed coal fired generators?

Mr. REED. This is something that we have not tested. We are aware that materials equivalent to this in volatile matter which is an important aspect of burning, have been successfully burned. It is a part of the next phase of the pilot program to run the boiler test.

Senator MUSKIE. Does deletion of the funds in the Interior Department's budget for 1968 reflect any lack of confidence on the part of the Department in the potential of this process, to the best of your knowledge?

Mr. REED. To the best of my knowledge, no. We understand that Mr. Fumich, Director of the Office of Coal Research, has testified that this deletion occurred at the Bureau level and that it was based on fiscal consideration.

Also the Office of Coal Research has had an independent outside evaluation plus the fact that after the evaluation the Office of Coal Research did sign a contract last September and there has been essentially no new technical information.

Senator MUSKIE. Fine. Thank you very much, Mr. Reed, for your testimony and for waiting until so late in the day to testify.

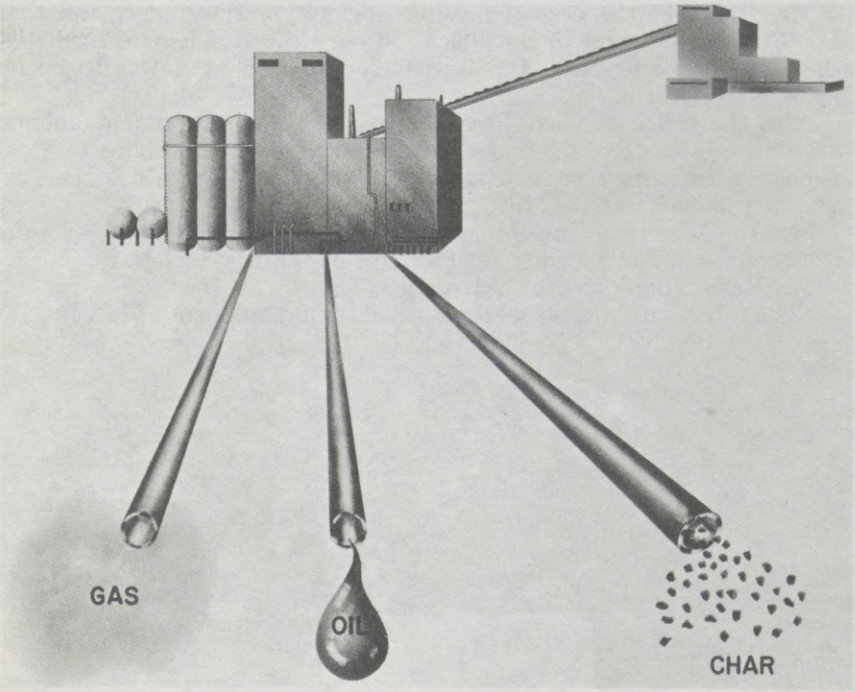
Mr. REED. Thank you for hearing me.

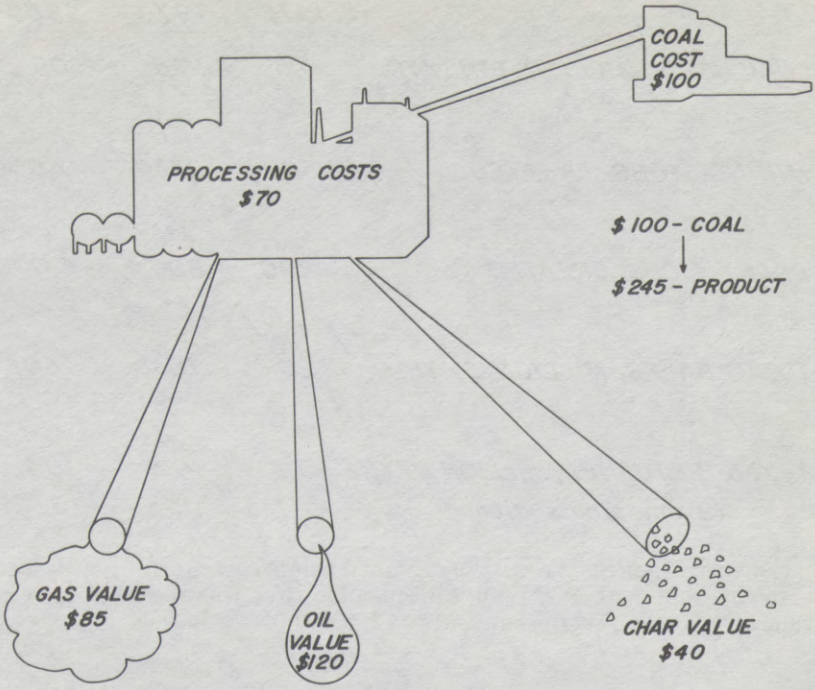
(The following exhibits were attached to the statement of Mr. Reed:)

COED

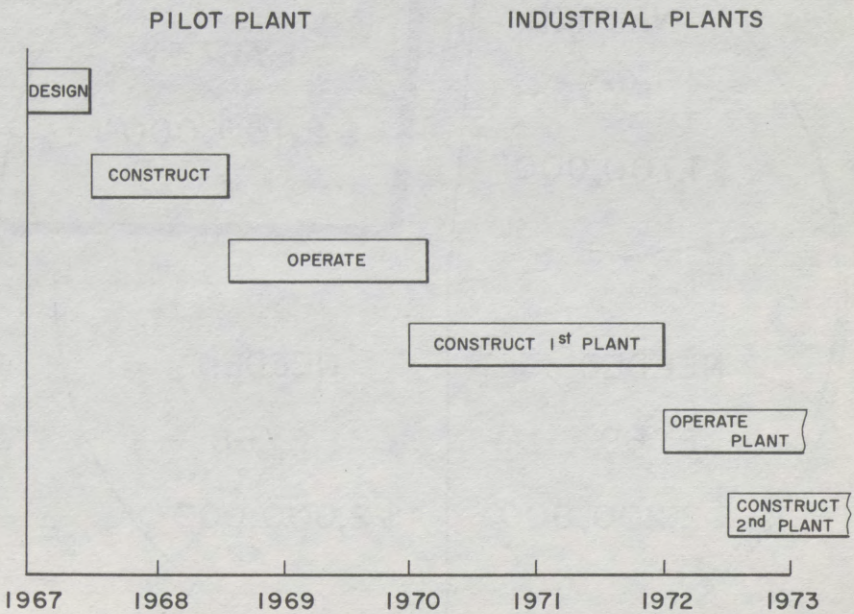
char oil energy development

A PROCESS FOR CONVERTING BITUMINOUS COALS TO MORE VALUABLE PRODUCTS





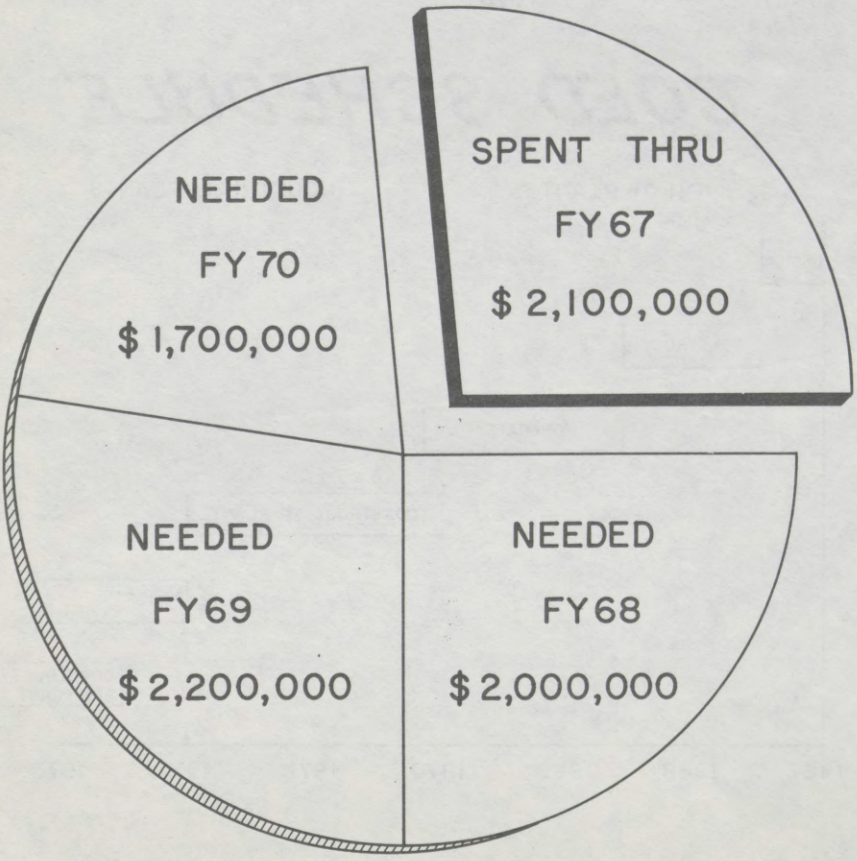
COED SCHEDULE



	1972	1976	1980's
COAL USED, MILLION TONS/YR.	3.5	10.5	105
MINING JOBS CREATED	500	1,350	12,000
PLANT JOBS CREATED	200	600	6,000
TOTAL SALES, MILLION $/YR.	25	75	750
TAXES RETURNED, MILLION $/YR. (from plants alone)	3.5	10.5	105

Senator MUSKIE. We will recess until tomorrow morning at 9:30.

(Whereupon, at 1:30 p.m., the subcommittee was recessed, to reconvene at 9:30 a.m., Wednesday, May 17, 1967.)



AIR POLLUTION—1967

WEDNESDAY, MAY 17, 1967

UNITED STATES SENATE,
SUBCOMMITTEE ON AIR AND WATER POLLUTION
OF THE COMMITTEE ON PUBLIC WORKS,
Washington, D.C.

The subcommittee met, pursuant to recess, at 9:35 a.m., in room 4200, Senate Office Building, Senator Edmund S. Muskie (chairman of the subcommittee) presiding.

Present: Senators Muskie, Randolph, Spong, Boggs, Baker.

Also present: Richard B. Royce, staff director; Leon G. Billings and Richard D. Grundy, professional staff members; and Richard E. Gerrish, minority staff director.

Senator MUSKIE. The hearing will be in order.

Our first scheduled witness this morning was Senator Ribicoff who, unfortunately, has a conflict so he has submitted a prepared statement which we are delighted to receive and put in the record. He has a long record of interest and effective effort in this field and the hearing would not be complete without some expression of his support. We are delighted to have that statement.

(The statement referred to follows:)

[News release from Senator Abraham Ribicoff, May 17, 1967]

SUPPORTS AIR QUALITY ACT

WASHINGTON, D.C.—Senator Abraham Ribicoff (D–Conn.), urging support for air pollution control legislation, warned today that the nation "may well be overwhelmed by pollution within the decade" unless action is taken now.

"The future health of the nation is at stake," Senator Ribicoff said. "We have turned our skies into sewers by pouring out 360,000 tons of pollution into our atmosphere every day—two and a half million tons of dirt a week.

"The number of pollutants in the air is increasing faster than other hazards of our modern environment. Almost every day a new chemical or process becomes part of our industrial development before we know whether it is harmful to health."

Senator Ribicoff's remarks in support of the Air Quality Act came in testimony submitted to the Air and Water Pollution Subcommittee of the Senate Public Works Committee.

Senator Ribicoff said that 7,300 communities in all parts of the country suffer from air pollution.

"There is no sanctuary to which we can retreat," he said. "The man who does not like dirty air can no longer escape by moving to the suburbs."

Senator Ribicoff recalled the air pollution crisis along the Atlantic Coast last fall and said it could happen again.

In the next 10 years, he said, the major sources of air pollution—cars, industrial production, electric power generation—will increase at a rapid rate and the population in urban areas will climb 30 percent.

STATEMENT OF SENATOR ABRAHAM A. RIBICOFF (D-CONN.) OF S. 780, THE AIR QUALITY ACT, BEFORE THE SUBCOMMITTEE ON AIR AND WATER POLLUTION, SENATE COMMITTEE ON PUBLIC WORKS, MAY 17, 1967

Mr. Chairman, I am happy to testify today in support of the Air Quality Act of 1967, and to commend the outstanding leadership of the Chairman (Senator Muskie) in this field.

For many years, air pollution has been called "the invisible menace." We could not see it. We could not smell it. And when it caused death and destruction, we wanted to forget it. Air pollution was both out of sight and out of mind.

But today, all this has changed.

An increasing number of tragedies and close calls—such as the air pollution emergency along the Atlantic coast last Thanksgiving—demands that we face the seriousness of this problem.

Only two months ago, a Harris poll showed more public support for increased Federal pollution control efforts than for any other domestic program.

Clearly, this is a time for action. We in Congress, as elected representatives, are duty-bound not only to pass this air pollution legislation, but also to make sure that it is fully funded.

The Congressional response in this field has been excellent. Legislation has been passed in each of the past five years. But the growth of the problem has outdistanced our efforts. We are barely holding our own in the battle against air pollution—and that is not enough.

As Dr. John Middleton, director of the National Center for Air Pollution Control, told this Subcommittee:

"In 1980, the air quality will be no different from today. We must have a significant breakthrough to make any improvement."

I believe that S. 780 offers that significant break-through.

The proposed Air Quality Act of 1967 will provide for a better organization of our total national effort in controlling air pollution.

Although Federal activity, authority, and expenditures would be increased, state and local governments would continue to carry primary responsibility for enforcement of pollution control standards. The role of private industry also would be enlarged.

Three important and long-overdue innovations are contained in S. 780.

First, the Secretary of Health, Education, and Welfare would be authorized to establish uniform standards for specific pollutants on an *industry-wide* basis. In setting the standards, the Secretary would consult with industry and other interested parties. Uniform standards would put all states on a more equal footing with regard to air pollution control. The risk of an exodus of industry from a state or jurisdiction with controls to one without controls would be minimized. While states would be free to adopt higher standards, the point remains: There would be uniform minimum standards on an industry-wide basis. In addition, the existence of uniform standards would prevent industrial polluters from gaining an unfair competitive advantage over firms which do invest in pollution control.

Second, the Act would authorize the establishment of regional air pollution commissions. The absence of these regional organizations is a weakness in our current defense against air pollution. Air pollution knows no political boundaries. Our agencies of control must be organized according to our problems, not our politics.

Third, this Act would permit the Federal Government for the first time to provide funds to private industry for the development of air pollution control demonstration projects.

The future health of our nation is at stake. There is no sanctuary to which we can retreat. The man who does not like dirty air, whose eyes are irritated, whose throat is inflamed, whose lungs are congested, can no longer escape by moving to the suburbs or to another city. More than 7,300 communities all across the country, from the smallest town to the largest metropolis, are beset by air pollution.

We have turned our skies into sewers by pouring out 360,000 tons of pollution into our atmosphere every day—two-and-a-half million tons of dirt a week. In addition, the number of pollutants in the air is increasing faster than other hazards of our modern environment. Almost every day a new chemical or process becomes part of our industrial development before we know whether it is harmful to human health.

During the next decade the sources of air pollution will grow at a rapid rate. The number of motor vehicles will increase by a third. Industrial production will increase by more than half, and our generation of electric power will more than double. This will occur while the population of our urban areas increases by 30 per cent. These figures make it clear that the time for imaginative, aggressive action is now. If we wait, we may well be overwhelmed by pollution within a decade.

It would offer the means by which we can begin to restore our skies to the pure state which our Forefathers were able to take for granted.

I urge that the Subcommittee take favorable action on S. 780.

Senator MUSKIE. Our first witness this morning will be Dr. John Middleton, Director of the National Center for Air Pollution Control of the Public Health Service.

I have asked Dr. Middleton to meet with us again this morning in order that we may further explore with him the content of the national emission standards, a subject which has had perhaps more than its share of attention in these hearings. Nevertheless, I think it is important that we fully understand what we propose, its implications, and the problems connected with it, so I thought it would be appropriate to invite Dr. Middleton to address himself to the subject.

I am particularly interested in focusing upon what is meant by minimum national standards. We started talking about national emission standards and then we began to talk about minimum national emission standards. I think we should know what that means.

Dr. Middleton, I note you have a prepared statement which we will be delighted to have you go into now.

STATEMENT OF DR. JOHN MIDDLETON, DIRECTOR, NATIONAL CENTER FOR AIR POLLUTION CONTROL, PUBLIC HEALTH SERVICE; ACCOMPANIED BY DR. EDWARD T. BLOMQUIST, ASSOCIATE DIRECTOR FOR STANDARDS AND CRITERIA DEVELOPMENT PROGRAMS; THOMAS F. WILLIAMS, CHIEF, OFFICE OF LEGISLATIVE AND PUBLIC AFFAIRS, AND DR. JOHN H. LUDWIG, ASSOCIATE DIRECTOR, CONTROL TECHNOLOGY RESEARCH AND DEVELOPMENT

Dr. MIDDLETON. Thank you, sir.

Mr. Chairman and members of the subcommittee, I appreciate your inviting me to testify again at these hearings on the proposed Air Quality Act of 1967.

In accordance with your invitation, my remarks this morning will be focused on those provisions of the legislation which would authorize the promulgation of national emission standards for the control of major industrial sources of air pollution.

I outlined the principal considerations that are germane to the establishment of Federal emission standards, as you may recall, Mr. Chairman, in the testimony I presented on April 19.

I should like at this time to offer just a few brief comments, which, I hope, will help to clarify certain points that seem to have been misunderstood by many of the witnesses who have testified since my appearance last month.

These comments, I am sure, will provoke some additional questions

77-515 O—67—pt. 4——19

from you and the members of the subcommittee, which, in all likelihood, will produce an even greater degree of clarification.

The sources for which national emission standards are needed are the responsibility of industries which form the backbone of our economy. They include the electric power industry, petroleum refineries, iron and steel mills and other metallurgical operations, manufacturers of chemicals, and pulp and paper mills.

They include many firms that operate on a national scale. Of necessity, their policies are decided and their activties planned on the basis of nationally significant economic considerations.

The setting of national emission standards under the proposed Air Quality Act of 1967 certainly would not mean that we could quickly control all the significant air pollution problems associated with industrial operations. There are still many industrial sources of air pollution for which economically and technically feasible control methods are not available.

The solution to these problems clearly will require intensified research and development, by both government and industry. But there are many other industrial operations which are responsible for substantial air pollution problems and which can be controlled now and at costs which are clearly justified by the benefits that would be derived. The proposed Air Quality Act would enable us to begin attacking these problems.

Emission standards would be established primarily on the basis of the degree of control needed to prevent pollution from existing industrial sources from producing adverse effects on health and welfare.

These standards would necessarily be set industry by industry and pollutant by pollutant; that is, standards for control of particulate matter, for example, would be the same for all plants within a given industry but different from those for other industries.

There are two limiting factors that we would give first priority in establishing national emission standards. The first is that we would develop emission standards to curtail pollution only to the degree necessary to avoid adverse effects on public health or welfare.

The second is that we would develop standards only for those sources of pollutants which can be controlled through the application of available, economically, and technically feasible control technology.

Both these factors would have to be satisfied before we could promulgate a Federal emission standard for any given pollutant from any category or source.

To satisfy both these conditions is not as easy as some may think. There are severe limitations on the technology now available for controlling many important sources of air pollution.

Moreover, the direct adverse effects on public health and welfare of pollution from major sources are sufficiently great that full application of existing technology would be required in most instances, to partly or totally obviate these adverse effects.

In view of these facts, much of the controversy about whether or not we might overcontrol certain sources of pollution is extremely academic.

Let me cite a few examples which illustrate the point that single sources of air pollution can, in themselves, injure public health and

welfare. These examples are drawn from our experience in Federal proceedings for the abatement of interstate and, in one instance, intrastate, air pollution problems.

In three of the areas in which action has been taken to abate interstate problems, only a single source of pollution was involved; in one instance, it was a rendering plant, in the other two, pulp mills. In all three instances, the single source was, in itself, a threat to public health and welfare.

A similar situation is alleged to exist in an intrastate area where Federal abatement action has recently been requested by the Governor of Montana; in this instance, the single source is a phosphate fertilizer plant.

While these are but a few examples, there are many industrial sources which adversely affect public health and welfare, in and of themselves—ambient levels of pollution from other sources notwithstanding.

But we are fully aware that the vast majority of significant sources are located in urban areas. Thus, in developing emission standards, we are prepared to calculate an urban factor which would insure that the standards would not be developed against an unrealistic background of perfect air purity.

Since most industrial sources are, as I have said, located in urban areas, few would be subjected to emission standards that did not take into account the general urban levels of pollution. And since current technology would have to be fully applied to protect health and welfare even with regard to those sources located in areas of relative air purity, we can see that a very few sources, indeed, would not be affected by uniform national standards.

We believe that the degree of uniformity which would be achieved by the application of national emission standards would be extremely beneficial to the health and welfare of citizens in every region of the country. Not only would they provide the direct benefit of lowering levels of pollution; they would, in addition, enable State and local control officials to devote a greater degree of effort to lowering levels of pollution from the many sources which would not be affected by national standards. Their application would also make quite clear the limitations in current control technology and point up needs for further research and development.

This, then, is the statement that bears on the point of minimum national standards.

Senator MUSKIE. Well, I think it gives us an excellent starting point for further discussion.

First of all, I think you make the point in your statement that these standards are necessarily related to the results they produce in the ambient air in these words, and I quote:

"Emission standards would be established primarily on the basis of the degree of control needed to prevent pollution from existing industrial sources from producing adverse effects on health and welfare."

Now, if I read those words correctly, what they say is that a national standard that is unrelated to that goal of preventing adverse effects on health and welfare is not intended.

Dr. MIDDLETON. Yes.

Senator MUSKIE. So that, when you are talking about industries that ought to be subject to national standards, you are talking about

industries that would produce an ambient air quality which is harmful to health, whatever the location of the plant; is that correct?

Dr. MIDDLETON. That is true, Senator.

Senator MUSKIE. Now, what foundation of knowledge is there which can tell us now any of the industries you have named that will produce an ambient air quality that has adverse effects on health and welfare, wherever they are located?

Dr. MIDDLETON. May I refer you to the remarks made by Dr. Blomquist in which he was describing the effects of pollutants for specific periods of time on human health and adverse effects upon welfare.

It is the development of these criteria, some of them partially along the way, you will recall, and some in the process of evolution, that will in fact describe a scientific foundation and best knowledge for the point that you bring up. This is not now all immediately available.

We tried to point out to you the nature of the criteria, the kinds we are being concerned with and how they would be evolved.

Senator MUSKIE. The quality of ambient air depends not only upon the pollutant which is being emitted into the air but also upon meteorological conditions, the natural ventilation that is available in a particular location. Is that not true?

Dr. MIDDLETON. That is true and this, of course, bears on the very important point of the quantity of the materials being emitted so that the amounts coming from particular industry would be determined by source emission studies such that we could relate the quantities both from the source as affected by meteorology in the specific location—the several points.

Senator MUSKIE. The point I am making is this, that since meteorological conditions are variable and since the natural ventilation of a location is variable, must not then the pollutant be a variant if the result that you are undertaking to evaluate is a level of ambient air quality that has an adverse effect upon health because that is not a variant?

I take it that although it may operate within ranges that the result we are talking about is as definite and precise a result as you can arrive at; that is, that at some level a given pollutant will produce adverse effects upon the health of human beings or plant or animal life.

Dr. MIDDLETON. Yes, sir.

Senator MUSKIE. We finally determine what is a fixed factor.

Since two of the other three factors are variables, then it seems to me the third must be a variable, depending upon location. Is that a correct analysis?

Dr. MIDDLETON. Yes, sir.

The several factors that you point out are the variables, in fact, which should be used in the development of the emission number which relates the amount of pollutants, their source strength, that is, and the factors that would pollute and carry it off.

That is why we bring into account not only the direct emission from the particular source but also the background level so that the effect is related to the amount coming out, its distribution depending upon terrain and the weather conditions that would disperse it which relate again to the variabilities about the factors that you have enumerated that in turn bear upon the dilution of the specific source strength.

Senator MUSKIE. We are talking about national standards.

Now, let us define the idea of standards a little more.

Standards are built upon criteria, as I recall your explanation in your first appearance before the committee. So, standards are the means, including the timetable, for putting criteria into effect or implementing criteria.

Now, if the criteria vary depending upon meteorology and ventilation of an area, then are not also the standards going to have to vary to achieve the same results in different locations across the country?

Dr. MIDDLETON. The point is, Senator, I think there will always be variabilities but the specific materials being emitted may not be dispersed such that there is this uniformity.

Senator MUSKIE. Those times are going to vary from place to place.

Dr. MIDDLETON. They will vary from place to place but surely those are the minimum numbers for those particular moments wherever they may be; they cannot result solely as the vagaries may affect them. If there are no winds, it is that particular concentration at that ground level amount that will have the direct adverse health and welfare effect.

Senator MUSKIE. I am saying this on the basis of what seems to be clearly indicated. Since all of these factors vary, how you deal with them, what you do with them, and how you implement health criteria, which is the meaning of standards, is going to have to vary from place to place.

So, how do you on a national basis arrive at a common denominator of standards that is going to hit all these variables?

Mr. WILLIAMS. Senator Muskie, among the variables that we have to consider is the existence or nonexistence of adequate control technology for various pollutants from various sources. Technology is a limiting factor as to what you can do right now about pollution to a greater extent than is anything else.

To control a large pollution source of the kind we are talking about in such a way as to protect public health and welfare in the vicinity of its plume or its emission, in most cases, you would have to apply technology to the full limits of current capability.

Even if you calculated ambient air levels, background levels and needed a greater degree of control, you would not be able to apply it. There are two factors, sir.

Senator MUSKIE. It seems to me what you are saying is that they ought not to take risks because you use the word "problem." You probably have to use full technology so you think you ought to take the risk of overcontrol rather than the risk of undercontrol. Is that what you mean?

Mr. WILLIAMS. No; we don't think that there would be any risk with regard to that since no matter to what extent we control a source, the degree of control would—it will be related to measurable and demonstrable effects on public health and welfare.

Senator MUSKIE. When you finally reach the point with respect to particular industries and apply a national standard, you are not going to be able to measure the air quality in all of the locations in which that industry operates under different companies and so on. So you cannot say, can you, that your national standards would be based on an actual measurement of the ambient air quality in all of these locations?

Dr. LUDWIG. May I comment on the meteorology involved in this situation. The point is that the meterological conditions which affect the general level of air pollution over an entire community are different than those that affect the contribution from a single plant.

It would be my opinion here that we would apply a number of meteorological regimes including that known as the light wind limited mixing condition to determine the contribution of a single plant to the ground level concentrations in the immediate vicinity of this plant. This condition exists in many parts of the country.

Now, at other times, for example, during a general stagnation period—we have heard about the one that occurred last Thanksgiving in New York and south of New York over the Appalachian area—there is a general buildup of pollutants over a period of several days.

Senator MUSKIE. The criteria are designed with respect to the health impact of given pollutants. Am I correct?

Dr. LUDWIG. Yes.

Senator MUSKIE. Now, that is going to depend upon the concentrations of those pollutants; is it not?

Dr. MIDDLETON. Their exposure time as well.

Senator MUSKIE. Concentrations and length of exposure.

Dr. MIDDLETON. Yes, sir.

Senator MUSKIE. Are those not going to vary from place to place in a given industry?

Let's say we take a steel mill of a given capacity identical in all of its aspects to a number of others located in different parts of the country. Now, the emissions for a given stack of that plant are going to have a different impact upon the ambient air quality of that community, depending upon meteorological conditions, upon natural ventilation; aren't they?

Dr. LUDWIG. Yes. Under meteorological conditions that an individual stack contributes to its immediate surroundings, conditions that are generally applicable across the Nation for this particular industry.

Senator MUSKIE. But the length of the periods of light wind conditions are going to vary; isn't it?

Dr. LUDWIG. This is true.

Senator MUSKIE. And the time of day is going to vary; is it not?

Dr. LUDWIG. That is true.

Senator MUSKIE. And the variations come late in the morning and in the afternoon and they will not coincide with light wind conditions; will they?

Dr. LUDWIG. This light wind condition and other conditions are not conditions that are connected with inversions.

Senator MUSKIE. I understand.

Dr. LUDWIG. I think we must recognize that the procedure for establishing ambient or ground level concentrations is going to have to consider various items such as the height of the stack and the removal of the stack from public property, things of this sort, so that I don't think we are talking of an emission standard based on one single number.

Senator MUSKIE. Then how do you get one single national standard?

Dr. LUDWIG. I think what is meant by one single national standard is a single table of numbers or one model. In other words, the way I

see this you would have an emission standard which would take into account the height of the stack involved.

Senator MUSKIE. In other words, when you are talking about a national standard for a particular pollutant from a particular industry you are not talking about one national standard, you are talking about a table of standards?

Dr. LUDWIG. A table of numbers which relates——

Senator MUSKIE. Those are going to be different standards undertaken to take into account varying conditions; are they not, from what you have said? You said it depends upon stack height, among other things.

Dr. LUDWIG. Yes.

Senator MUSKIE. That is going to vary. What other factors will vary in this table you are talking about?

Dr. LUDWIG. The amount of material that is being emitted—the quantity, the distance from this stack to public property, the height of the stack itself, the buoyancy of the emissions—all of these things have to be taken into consideration in this table of emission standards.

Senator MUSKIE. How about the fact that you may have new plants, old plants? You are going to take that variable into consideration?

Dr. LUDWIG. As Dr. Middleton indicated here today, consideration would be given to the general urban background versus the rural background to establish the contribution that this particular plant could make.

Senator MUSKIE. In other words, you will have a national urban standard and a national rural standard?

Mr. WILLIAMS. May I comment on that, please?

Senator MUSKIE. Yes.

Mr. WILLIAMS. I think the point Dr. Middleton has made in his prepared statement is that there are severe limitations on the technology for control and that even though you would consider urban background levels of pollution in setting your emission standards for urban areas, you would probably, without considering background levels—and I say probably because we have not tested out every single one of them—take care of the rural areas by applying the same degree of control. The direct adverse effects on health and welfare from these gross sources of pollution would require the full application of technology in rural areas just as it would in urban areas.

Senator MUSKIE. That is a hypothesis at this point; is it not?

Have you in fact actually identified under all conceivable local conditions, meteorological and so on, any industry or any pollutant from any industry which creates an undesirable impact on health wherever it is located? Have you actually made such a finding?

Mr. WILLIAMS. We feel that there are so few that would escape that it would probably be unwise for us to check them all out, sir.

Senator MUSKIE. But up to this point you just have a feeling about them.

Dr. MIDDLETON. What we are saying, Senator——

Senator MUSKIE. I am just using your words, Mr. Williams.

The question is susceptible of a direct answer. In your basic assumption, Mr. Williams, you said that the condition of the particular industry is so obviously deleterious to health that the full technology must be

applied. I think in order to make such a statement you ought to be able to tell us the actual finding that that is the case in the particular industry in a given pollutant.

Have you found that there is such an industry and such a pollutant wherever it is located, under whatever conditions, meteorological, wind, topographical? Have you made such a finding?

Dr. MIDDLETON. I am quite certain with the vast number of industries that there are throughout the United States we have not had the opportunity to evaluate each of these instances that you have clearly set forth.

Senator MUSKIE. I was sure that was the case.

Dr. MIDDLETON. The assumption, sir, in this case is based on there being a receptor, something to receive. If, in fact, there are the criteria which express relationship to any effect of the pollutant concentration and time on the receptor, this sets the stage for what kinds of pollutants for what time periods we should be concerned with.

If, in fact, there is no receptor, nothing to receive the pollutant such as you may imagine as a plant in the middle of White Sands, N. Mex., with no people, then there would be no need to control this industrial source of pollution. This could be an obvious exception to national minimum emission standards.

It is in this framework that one can make predictions of the need to control to these minimum standards.

I would like to rephrase it in the sense that when we talk about minimum standards, minimum national standards for particular industries and particular pollutants, we are talking about, as the engineer says, a family of curves such that there is no one number that has national applicability, no arbitrary figure of, let me say, 95 percent reduction.

But under the variable weather conditions when there are those quiet periods in which the effluent predictions can be capably predicted, that maximum pollution period is the period of greatest concern because there is no ventilation, there is not even a light wind. So, it is on the basis that one puts together the source strength, the size of the plant, the stack height, the buoyancy, and other factors of discharge, that not a single number, but a set of curves, describe national emission standard applications for those particular kinds of industries for their particular dimension.

Senator MUSKIE. What you are saying is that because of the variables, climatic conditions, local conditions, and so forth, you have to pick a set of conditions, which is the best time or the best condition to measure the health impact of the air quality.

Dr. MIDDLETON. Yes; the most adverse situation in that locality.

Senator MUSKIE. So that has to do with the criteria.

Dr. MIDDLETON. That has to do with the time that the person is there to receive the pollutant.

Senator MUSKIE. But that is the criteria; that is not the standard.

Dr. MIDDLETON. That is the effect of the pollutant for the exposure time on the receptor.

Senator MUSKIE. You have set up the perimeters of the local conditions which you think are the best——

Dr. MIDDLETON. They describe best the adverse effects on the receptor.

Senator MUSKIE. But which give you the best clue as to what the effect on health is.

Dr. MIDDLETON. Yes.

Senator MUSKIE. And that is what you regard as your criteria.

Now, your standard is your way of implementing that criteria.

Dr. MIDDLETON. It is the adaptations that have to be made to reach that point.

Senator MUSKIE. How can you have minimum and maximum standards? I mean, if that is the result that you have to produce, then is there only one standard?

Dr. MIDDLETON. The minimum standard is related to those first adverse health and welfare effects. This is the minimum national standard. Depending upon these effects it will be variable by industry and location because of the variables that relate to the amounts of pollutants pouring out.

Senator MUSKIE. Well, I am going to ask my colleagues if they want to question on this point a while while I continue to try to grasp it myself. I will say this and yield to my colleagues.

It seems to me that you cannot go about the business of setting a national standard simply on the assumption without some finding that a given pollutant from a given industry would inevitably under all conditions produce harmful health effects.

Now, if you don't make that assumption, I don't think you should, and you can't make the finding or have not, then it does not seem to me you are in a position to argue for national standards in the sense that I understand national standards.

Dr. MIDDLETON. Senator Muskie——

Senator MUSKIE. Let me just finish.

Dr. MIDDLETON. Excuse me.

Senator MUSKIE. On the other hand, when you talk about national standards, it seems to me you seemed to indicate at this point you are talking about a table of variable standards which take into account several variables—the amount of pollution that is emitted, the stack height and rural and urban regions, old and new plants, maybe other variables.

I am not talking about a table of variables. Then you are not talking about national standards.

Dr. MIDDLETON. I beg to differ with you, sir.

The point is that the effect of the pollutant for a particular period of time under the predictable nondilution system of the industry pollutant is in fact a minimum standard. How one achieves that particular control depends upon the degree to which one restricts the particular effluent, the stack height, the plant size, and the emission inventory that one has to make.

These are the variables, but they in no way detract from the minimum national standard. These variables provide the latitude within process evolution and change that allows the establishment of the particular standard levels.

So, we have a set of variables that one uses for the restraints in the industry which would vary, as you have been talking about, but the effluent from that point is in fact a minimum level.

Since these refer to national sources of significance, this is a national minimum standard. How one achieves that is what is variable, not what the standard shall be.

Perhaps that should clarify the issue further.

Senator MUSKIE. In your testimony of April 19, you said this, and I quote:

> Quality criteria are an expression of the scientific knowledge of the relationship between various concentrations of pollutants in the air and their adverse effects on man, animals, vegetation, materials, visibility and so on.
>
> Air quality criteria can and should be used in developing air quality standards. Criteria and standards are not synonymous. Air quality criteria are descriptive; that is, they describe the effects that can be expected to occur whenever and wherever the ambient air level of a pollutant reaches or exceeds a specific figure for a specific time period.

That concept I understand; you have made it very clear.

Then you go on:

> Air quality standards are prescriptive; they prescribe pollutant levels that cannot legally be exceeded during a specific time in a specific geographic area.

Now, if that is a definition of a standard, something that prescribes pollutant levels but cannot be legally exceeded during a specific time period in a specific geographic area, then how do you have a single national standard?

Dr. MIDDLETON. Because of the direct immediate effect of the effluent, the pollution from a specific industrial source which has its own immediate impact at the ground level.

Senator MUSKIE. Which implicitly in your language of April 19 would differ in one specific geographic area from that in another specific geographic area.

You follow it with this sentence:

> Ideally the area should be the entire region that shares a common air supply and thus shares the impact of pollution from all sources in the region.

Dr. MIDDLETON. Yes, sir.

Senator MUSKIE. Now, that language emphasizes, Dr. Middleton, it seems to me, that the air pollution of one area sharing one common air supply can differ even with the same pollutant sources from another area with a different common air supply. Otherwise, why did you emphasize the specific area?

Dr. MIDDLETON. Yes, sir; that statement is——

Senator MUSKIE. It is an excellent statement.

Dr. MIDDLETON. That statement is correct and valid and that now is what I am not able to persuade you further about this morning.

Senator MUSKIE. Well, it is not a question of persuading me; it is a question of explaining.

Dr. MIDDLETON. I will retreat to the classroom once again.

Senator MUSKIE. You have got a willing student.

Dr. MIDDLETON. Usually the professor speaks to his students, does not have an audience behind him, and does not perform in the arena here so different than the University of California.

Senator RANDOLPH. Mr. Chairman.

Senator MUSKIE. Senator Randolph.

Senator RANDOLPH. May I interrupt to tell a story? There was a mountaineer who was disappointed in the reaction of his son and talked with him and finally blurted out, "Son, are you listening?"

The boy replied, "Yes, pappy, but I ain't payin' no attention."

I assure you we are paying attention to what you are saying, Dr. Middleton, but it is complex; it is difficult; and yet we could find the answers with the help of all of us working at this table as well as that table.

Dr. MIDDLETON. Senator Randolph, I enjoy your patience.

Thank you, sir.

The statement I made April 19 which you were kind enough to reread does clarify the relationship of criteria to ambient air quality standards. It is true that these levels of pollution will vary from place to place; therefore, the necessity of handling them on a regional basis.

The levels of pollution in Los Angeles are very different than the levels of pollution in New York City. The automobile has a variable role in pollution in different places, depending upon the amounts of other kinds of pollution; that does not detract from the importance of the several sources—automobiles and stationary sources.

What I am trying to put across, not persuade, demonstrate, is that regardless of the mixture of pollutants and maybe their differences from place to place, one would expect differences depending upon degrees of control of various sources, that wherever you are, whatever the ambient air background differences, there will be the immediate effect of the single significant national industrial source of pollution. This is either alone or it is added to the ambient air pollution levels.

Therefore, the ambient air quality standard for the moving pollution cloud is one item of importance.

The second item of importance is, regardless of this cloud—and this will happen when this cloud does not move, there is the direct immediate effect of the single significant source imposed on the receptors, be they man, beast, plants, or the quality of the air itself.

It is this immediate effluent effect that I speak of as the industrial source; it is an emission that needs to be controlled. The degree of control is dependent upon the size of that source, and the variables that Dr. Ludwig spoke to.

So, the ground level concentration of that emission provides the minimum tolerable base on the criteria for that pollutant. This is the second part of the contribution of the pollution in the region.

That is why I can say quite frankly there are national emissions, that there need to be minimum national emission satndards which take into account the losses of these pollutants and their effects at a particular locale.

There is beyond that the effect on the ambient air itself, and therefore one needs to consider the regional or the airshed aspect requirements for ambient air quality standards.

Now, this minimum emission from the significant source, this emission standard is based on the particular effect of that effluent, and the family of curves describing the minimum emission standard does not mean anything more than the scientific basis for bringing about the particular restriction required to abate the particular direct effect of that industrial emission. That is the difference between the potiential of it and the singleness of its particular effect.

Senator MUSKIE. Now you succeeded in taking me back to the beginning and I understood the beginning before.

Now let me review just briefly and maybe this might get at it. You can challenge any one of these points I will try to make in the next 2 or 3 minutes.

First of all, you have said that a pollutant emission ought to be controlled only if it produces deleterious effects upon health, including human beings, plant and animal life. I am speaking of health in the sense that you have discussed it in these hearings.

Dr. MIDDLETON. Yes, sir.

Senator MUSKIE. Now, secondly, you have agreed that you have not yet made a finding as to whether there are particular pollutants from particular industries that have this inevitable effect upon health wherever the plant is located.

Dr. MIDDLETON. Not for all of them; no. We have done it for some.

Senator MUSKIE. Well, which ones?

Dr. MIDDLETON. We know, for instances, the adverse effect of sulfur dioxide coming from the sufuric acid plant as a specific example. We are not completely vacant in this information but we would not establish national emission standards until we had source inventories and much more information than we presently have. It is that part of the act that would permit acquisition of this information and then relating them to the casual events we are now speaking of.

Senator MUSKIE. But, you see, this is what the proposed section says:

> The Secretary shall from time to time by regulation, giving appropriate consideration to technological and economic feasibility, establish emission standards for all or designated emissions which (1) are from designated industries which because of their nature are sources of substantial amounts; and (2) can with reasonable effort and expenditures be prevented or substantially reduced.

Now, that does not say that these standards will be applied only where there is a demonstrable connection between the emissions and health. This says that this authority can be applied to industries which are sources of substantial amounts of pollutants.

Now, this does not require, as I understand it, a finding that in a given industry there be an inevitable connection between the pollution emissions and health.

Dr. MIDDLETON. The scientific evidence we have advanced here is an attempt to validate that we would prove that this is substantial or not and that it either has an effect or not.

Senator MUSKIE. Would you say that language requires that you make such a finding?

Dr. MIDDLETON. I would accede to your interpretation.

Senator MUSKIE. Don't accede anything.

Dr. MIDDLETON. I accede to your interpretation.

I would say that as a scientist I am not accustomed to making findings without considerable evidence, and I think that is the basis for my discussion here this morning.

Senator MUSKIE. So that you would agree that whatever other problems may be involved in connection with the concept this ought to be tied to a health effect.

Dr. MIDDLETON. This I have said.

Senator MUSKIE. A health effect in whatever location the plant may be located.

Dr. MIDDLETON. Yes, sir, wherever there is an adverse effect upon the health or welfare or where there is a subject to receive it.

Senator MUSKIE. And a standard ought not to apply in an area where it is not related to a health effect?

Dr. MIDDLETON. Quite correct.

Senator MUSKIE. Do you think that a finding ought to be made before national standards are applied that there is an inevitable health effect wherever that industry may be located?

Dr. MIDDLETON. That is the thrust of my testimony, sir.

Senator MUSKIE. Is it also your testimony that the answer would be different in that connection in rural and urban areas?

Dr. MIDDLETON. Depending upon the ambient background levels, there may be a need for a different view; yes, sir. Likewise, there may not be.

Senator MUSKIE. However, we may disagree in our understanding of the extent to which there may be variables in different locations?

Dr. MIDDLETON. There will be variables; I am not sure we really disagree. I think we are disagreeing perhaps in the relative weighting factors that we put into the formula for the categories of sources. I think that is only because we have not exploited the engineering talent well enough to describe this completely.

Senator MUSKIE. Let me ask you one more question and then I am going to yield.

Would it be possible for you to put together for us a suggestive table—it can be hypothetical—illustrating what a national standard relating to a particular pollutant from a particular industry might look like? You can even call the industry "X" so you won't find yourself talking about a particular industry.

Dr. MIDDLETON. May I say, sir, we developed several of these yesterday afternoon.

Senator MUSKIE. Oh, good. You have anticipated this question. Do you have it with you, Dr. Middleton?

Mr. MIDDLETON. These are the kind one does when one is getting one's ideas sharpened up and I am not ready to give it to you yet.

Senator MUSKIE. Then we may expect to have them.

Dr. MIDDLETON. Yes.

(Subsequently the following information was submitted:)

The following is an example of a hypothetical national emission standard for an industrial process:

For this example, we have selected sulfur dioxide emissions from sulfuric acid manufacturing plants using the contact process. On the basis of air quality criteria for sulfur oxides, we selected hypothetical ambient air quality standards for sulfur dioxide of 0.10 ppm (parts of sulfur dioxide per million parts of air) for a 24-hour average; 0.25 ppm for a 1-hour average; and 0.5 ppm for a 5-minute average. It was assumed that the maximum ground concentration of sulfur dioxide attributable to the source to be regulated should not exceed 35 percent of the air quality standard in an area of moderate or low pollution; and 20 percent in an area of relatively high pollution.

Based on the above discussion and considering available technically and economically feasible means for reducing emissions and using meteorological dispersion formulas, the attached Table I of allowable emissions of sulfur dioxide and minimum stack heights was prepared for plants of various sizes located in each of two types of areas as defined in Table II.

In some areas it may be necessary to require even more restrictive emission control. It may also be necessary to provide for pollution reduction or maintenance of existing levels by means of land use controls and emission reduction require-

ments applicable to other sources of pollution. This responsibility would rest with State and local governments.

This hypothetical standard, for the sake of brevity, does not include many of the details that might need to be incorporated in an actual standard.

TABLE I.—*Hypothetical emission standards and stack height requirements for contact process and sulfuric acid plants*

Plant capacity (tons of 100 percent sulfuric acid per 24-hr. day)	Maximum allowable emission of SO_2 in tons per day by type of area [2]		Minimum effective stack height in feet [1] by type of area [2]	
	Type A	Type B	Type A	Type B
100	2	1.5	145	150
300	6	4.5	230	270
500	10	7.5	280	320
700	14	10.5	325	370
900	18	13.5	350	400

[1] Minimum effective stack heights can be decreased if emissions are less than the maximum allowable. The decrease in effective stack height will be in direct proportion to the extent to which emissions are less than the maximum allowable.
[2] See table II for definition.

TABLE II.—*Definition of areas* [1]

Type of area	Sulfur dioxide concentration parts per million [2]			Sulfur dioxide emission density tons per square miles per day [3]	Population in 1,000's [4]
	24 hour average	1 hour average	5 minute average		
A	0.0–0.05	0.0–0.12	0.0–0.25	0.0–1.3	Less than 200.
B	Greater than 0.05.	Greater than 0.12.	Greater than 0.25.	Greater than 1.3.	Greater than 200.

[1] Use sulfur dioxide concentrations if available; if not, use emission density; if neither is available, use population.
[2] Maximum values at any point within 1 mile of the plant after substracting the calculated concentration attributed to the source to be regulated.
[3] Average for the area within 3 miles of the plant to be regulated on a day of maximum emissions, not including the plant to be regulated.
[4] Population of the standard metropolitan area, or, if not in such an area, of the county in which the source is located.

Senator MUSKIE. I will yield to my colleagues for a while.

Senator BOGGS?

Senator BOGGS. I came in late.

Senator MUSKIE. Senator Randolph.

Senator RANDOLPH. Well, I came in late but that is not the reason I am not going to ask any questions.

I think that you have explored this matter very thoroughly, Mr. Chairman. Your role has been almost as prosecutor this morning.

Senator MUSKIE. That was not my intention.

Senator RANDOLPH. But you certainly probed this problem, and, Dr. Middleton, that is what you desire, is it not?

Dr. MIDDLETON. Correct, sir.

Senator RANDOLPH. I have no questions at this time, Mr. Chairman.

Senator MUSKIE. May I say at this point that I have respect for Dr. Middleton and I think we manage to communicate pretty well most of the time even here in the hearing room. I think it is important that I ask sharp questions and get sharp answers, and I think Dr. Middleton does pretty well in upholding his side of the exchange.

I am not trying to cross-examine but this is a troublesome thing and I just tried to satisfy myself in public, not in private, as to exactly

what it is that you people are driving at. I think it has been helpful this morning.

Dr. MIDDLETON. I always seek the truth myself.

Senator MUSKIE. Senator Baker.

Senator BAKER. Mr. Chairman, I have to confess that at this particular point I need to sharpen up my own thinking and make sure I fully understood the exchange between the chairman and the witness.

Without implying any degree of agreement or disagreement with the policy of uniform or variable standards or criteria as it relates to the final markup of this bill, let me make sure that I understand the basic thrust and the principal design of this legislation you review.

First, that the controlling consideration in the matter of the quality of the atmosphere is to establish a level or quality of the ambient air and that this is the overriding and controlling consideration determining whether or not we do or do not have a problem in the field of air pollution.

Dr. MIDDLETON. That is correct, and then the effort to do something about it.

Senator BAKER. A step at a time.

So that, the basic first criteria is that we accept some acceptable level of the ambient air.

Dr. MIDDLETON. Based on the criteria; yes.

Senator BAKER. Taking into account pollution from whatever source, taking into account the causal relationship between these pollutants and their impact on life and property which implies then once again that degree and length and concentration of exposure may be factors as well, and that, No. 2, the secondary subordinate or implementing aspect of the problem or of the design is that in order to accommodate this level of ambient air quality it is necessary to seek out and find and identify the sources and then to prescribe standards of emission levels which are in your best judgment calculated not to produce an overall ambient air quality effect which will be detrimental and harmful to life or property.

The second is the implementing aspect of the design; that is, seeking out the source and then establishing levels permitted from those sources that will not bring up the pollution level of the ambient air above the acceptable limits.

Dr. MIDDLETON. Yes, sir. There are two ways of pushing it up, one from the collection and one direct from the single source, if this is the intent of your comment.

Senator BAKER. That is the third point I am coming into.

Dr. MIDDLETON. Excuse me.

Senator BAKER. Before I get to point 3, there are a set of variables involved in both the ambient air quality and in the contributory effect of emissions themselves that deal with meteorological considerations with photochemical considerations, with geographical considerations and the like, so that we cannot predict with any degree of laboratory or scientific accuracy what the ambient air quality may be in a locality without examining a whole set of variables.

Dr. MIDDLETON. We can do that so that we can make better predictions; yes.

Senator BAKER. Which implies that the ambient air quality is not a ratio of relationship between the level of emissions on the one hand

and the quality of the air on the other uniformly throughout the country.

Dr. MIDDLETON. That is not true when one deals with a specific nonreactive source of pollution that does not contribute to some secondary atmospheric reaction.

I want to be sure that you understand this point, or at least that it is clarified here. Some pollutants that are emitted, as you have stated, contribute to secondary kinds of materials.

The photochemical air pollution problem and sulfur dioxide emissions contribute to the formation of some other chemical things, oxidants and sulfuric acid.

Carbon monoxide, as an example, so far as we know, does not contribute to the formation of other chemical species.

I think this has to be added, Senator Baker, within the framework of your discussion that there are those interactions with some pollutants and not with others.

Senator BAKER. Not a direct linear relationship between the level of emission and the quality of the air, there is not a direct linear relationship between the type of pollutants that finally result and the source of the pollutants which are emitted because there may be an interaction between the sources.

Dr. MIDDLETON. That is true except for those that don't interact, in which case you can trace the plumes.

Senator BAKER. All right.

Now, the third and final point I want to get to is the one I want especially to understand.

Notwithstanding these basic principles that support the thrust of this proposal, I tend to get the impression that you favor the establishment of a limiting basic primary emission standard for an industry or a source by reason of a secondary consideration; that is, that there is an immediate direct impact within a relatively small area surrounding the source itself translated into—for example, if you had a sulfuric acid plant, it might be that within a radius of a mile and a half that everybody's stockings would melt as has happened, by the way, in certain areas that I can identify?

Senator MUSKIE. Not in your State?

Senator BAKER. I am afraid so.

But the point of the matter is that there is a direct or primary impact within a certain small definable area which is attributable almost solely in most instances to this pollutant, to this emission.

Now, is this the justification in your mind for establishing some level of uniform emission standard or level for a particular industry where there is a demonstrable ill effect within a small radius of the source?

Dr. MIDDLETON. I hope that will come out of our discussions this morning; yes, sir.

Senator BAKER. But this is only indirectly involved with the matter of ambient air quality; it is almost a separate consideration; it is a local effect.

Dr. MIDDLETON. Yes.

Senator BAKER. So, really, we are dealing with two problems: the problem of the quality of the air overall has a homogenous envelope that affects rural areas and urban areas together with interaction of

air sheds, prevailing winds, and geographical conditions. That is one.

The other one, what happens to those souls who happen to live within a mile or two of a particular plant?

Mr. WILLIAMS. May I say something?

Senator BAKER. Yes.

Mr. WILLIAMS. I think it is important to realize that when you are speaking of the available technology for control most of it has been developed for the purpose of doing away with the second category of effects you have outlined; they have been developed to keep down gross emission levels from a single source. Very few of our control apparatus or very little of it was developed against a sophisticated background of knowledge about what is happening in the ambient air of any region.

Senator BAKER. More often than not these localized effects that you can identify and cope with are pretty energetic reactions; such as the fluoride reactions from aluminum plants, sulfuric acid mists from chemical plants, and the like.

Mr. WILLIAMS. Yes.

Senator BAKER. The point that concerns me and which we will ultimately have to come to grips with in finally writing legislation in this field is our lack of knowledge or at least my lack of knowledge of these direct primary results or the overall ambient air quality results we might anticipate, for instance, from sulfur dioxide or some of the less energetic pollutants.

As a direct example, it seems to me that a national emission level for a steam generating plant based on the dilatory effects of sulfur dioxide might be entirely speculative at this particular point as distinguished from the demonstrable effects of fluorides that are emitted in the aluminum plant.

How do you go about deciding what uniform national level you might set for a steam generating plant in the hills of West Virginia as distinguished from one on the banks of the Hudson when you don't have this demonstrable evidence at this point?

Dr. MIDDLETON. Based on the point you made of the immediacy of the effect of sulfur dioxide directly apart from the production of other products of sulfur dioxide, it may react and form other things in the ambient air.

Senator BAKER. Have we done this, Doctor?

Dr. MIDDLETON. Have we done what?

Senator BAKER. Established this casual relationship for sulfur dioxide?

Dr. MIDDLETON. I think Dr. Blomquist related the role of sulfur dioxides.

Senator BAKER. I am not sure I am satisfied with that, because I really suppose that from a clinical standpoint or purely chemical standpoint you could almost always assume some altering impact of sulfur dioxide or sulfur SOX intake by a living organism.

We had some testimony the other day from some of our friends in England who indicated that on the basis of most extensive scientific and clinical research they had not yet been able to identify a direct relationship between health hazard and SOX emissions in general.

Do you agree with that or disagree?

77-515 O—67—pt. 4——20

Dr. MIDDLETON. I agree that we disagree in the sense that they have their evidence for their position.

We have discussed in Dr. Blomquist's testimony the other day the enhancement of particles in the air upon the toxicity of sulful dioxide, so that in addition to whatever effects one may actually measure from sulfur dioxide, we have the additive or enhancement effects of the other kinds of pollutants in the air on the human body. To this point there is agreement; but to say that particles are more important than sulfur dioxide is a matter of debate.

Senator BAKER. Right.

Without getting too far to the technical side which would get me far beyond my——

Dr. MIDDLETON. That is not my intention.

Senator BAKER. What proof do we have that sulfur dioxide would have an unhappy effect on human life? What evidence on the contrary is there that it must be present with other chemicals or other pollutants or other physical substances in order to produce the effect we observed, if any?

Dr. MIDDLETON. There is evidence that sulfur dioxide under controlled conditions——

Senator BAKER. Do we have levels?

Dr. MIDDLETON. I don't have them at hand.

Senator BAKER. But we do have them as a matter of scientific information?

Dr. BLOMQUIST. Yes.

Senator BAKER. Do they occur in the free air in sufficient concentrations to demonstrate a direct causal relationship between sulfur dioxide concentrations in the atmosphere and the health of living organisms?

Dr. BLOMQUIST. As Dr. Middleton indicates, we have information from the laboratory using pure SO_2 and then we have to use for our evidence as to what actually occurs evidence from the Thanksgiving Day episode for example.

Senator BAKER. Let me interrupt just a second in the interest of time, if nothing else, and I am not once again trying to take one position or the other.

Can you tell me whether or not in laboratory studies you have established a level of concentration of SO_2 which will have a minimum effect on living organisms and, No. 2, do those occur in the atmosphere as we observe them?

Dr. BLOMQUIST. It is a little hard to answer just yes or no. Generally speaking, I think I would answer yes.

Senator BAKER. Why?

Dr. BLOMQUIST. Now it is true that we have in the laboratory evidence of pure or controlled atmospheres but they will not always duplicate what we find in the atmosphere.

Senator BAKER. Well, I am not trying to press and I am certainly not trying to be——

Dr. MIDDLETON. I shall be glad to supply additional information for the record.

Senator MUSKIE. Yes. I wish you would and address it to the specific two questions which Senator Baker asked. I think we do need

that answer in the record in light of all of the conflict we have had up to this point, documented to the extent that you can an answer to those two questions. I think they are a key to this legislation.

Mr. WILLIAMS. We are preparing, Mr. Chairman, a response to the two questions made when we last met here, a list of those sources and pollutants that we think in and of themselves sufficiently endanger health and welfare to be considered for Federal emission standards.

(Subsequently Mr. Williams submitted the following information:)

The evidence concerning the effect of sulfur dioxide, in the absence of any other air pollutants, is necessarily confined to that resulting from experiments conducted in laboratory exposure chambers, since, in the ambient air, there are always other pollutants present to one degree or another. In most communities, elevated concentrations of sulfur oxides are accompanied by elevated concentrations of particulate matter (and other pollutants) and therefore, the effect of sulfur dioxide alone is seldom relevant to the question of effects which may be expected in the urban population.

Experimental exposures of humans to sulfur dioxide alone, in air, have been concerned with taste, odor, pulmonary function, eye irritation and reflex responses. The exposure times have been varied from 3 to 60 minutes. The exposure concentrations have varied according to the biological response studied or the purpose of the experiment. Sulfur dioxide can be detected by taste in concentrations of 0.3 to 1 ppm (1) and Dubrovskaya (2) reported that sensitive people can detect its odor at concentrations of 0.5 to 0.7 ppm. Reflex responses occur at lower concentrations: Bushtueva (3) reported that cortical conditioned reflexes can be developed with 0.2 ppm for 10 seconds at several repeated intervals in one day and that desynchronization of the alpha wave in the electroencephalogram can be caused by a concentration of 0.3 ppm for 20 seconds; Dubrovskaya (2) reported increased sensitivity to light in the dark adapted eye during exposure to 0.32 ppm or more for 15 minutes. Alterations in respiratory function of healthy human subjects have been observed at slightly higher concentrations: Amdur (4) reported that 1 ppm for 10 minutes resulted in changes in respiration and pulse rates; Tomono (5) reported that 1.6 ppm for 10 minutes caused measureable bronchoconstriction. Both Lawther (6) and Nadel (7) reported that some of their "normal" subjects were extra sensitive to sulfur dioxide. Although experiments have not been conducted with people at concentrations below 1 ppm, Amdur (9) has shown that the airway resistance of guinea pigs is significantly increased by exposure to 0.16 ppm sulfur dioxide.

Concentrations of sulfur dioxide which cause these effects do occur in community atmospheres. Some data from the Continuous Air Monitoring Program of the National Center for Air Pollution Control are presented in the attached table 1. For example, maximum five-minute peak concentrations were 1.94 ppm in Chicago; 0.99 ppm in Cincinnati; 1.25 ppm in Philadelphia; and 0.87 ppm in Washington, D.C. Maximum hourly averages were 1.69 ppm in Chicago; 0.55 ppm in Cincinnati; 1.03 ppm in Philadelphia; and 0.62 ppm in Washington, D.C.

Many of the effects of sulfur dioxide occur at lower concentrations or are of greater magnitude in the presence of other substances. Particulate matter such as sodium chloride which does not cause bronchoconstriction increases the airway resistance associated with a given amount of sulfur dioxide (figures 1 and 2 on p. 2535) (10, 11). The response to sulfur dioxide and other particulate matter, such as sulfuric acid mist or sulfate salts, which do cause bronchoconstriction, is greater than would be expected from the responses of both components by themselves (12). Likewise sensory and reflex responses to sulfur dioxide and sulfuric acid mist are greater than would be expected from the sum of the responses to either alone (table 2) (13).

Airway resistance in a group of patients with either chronic bronchitis or asthma studied by Dr. Spicer (14) in Baltimore gave a linear response to 2-hour average sulfur dioxide concentrations in the city air ranging up to 0.46 ppm. In controlled laboratory experiments such subjects have not been studied, but it has frequently been postulated that they would be more sensitive to sulfur dioxide than subjects without airway disease. Furthermore, it is in these people with already elevated airway resistance that increases in airway resistance are of most concern.

TABLE 1.—*Sulfur dioxide* [1] *concentration (parts per million) at CAMP sites, by averaging time and frequency, 1962–64 (copied from reference 8)*

City and averaging time	1962–64				Maximum				Percent data available	Percent of time concentration is exceeded								
	Maximum	Minimum	M can	GM	SGD	1962	1963	1964		0.001	0.01	0.1	1	10	30	50	70	90
Chicago:																		
5 minutes	1.94	0	0.14	0.12	2.05	1.13	1.94	1.62	81	1.88	1.44	1.08	0.72	.034	0.17	0.09	0.05	0.02
1 hour	1.69	0	.14	.12	1.98	.86	1.69	1.12	81	--------	1.13	.98	.69	.34	.17	.10	.05	.02
8 hours	1.02	0	.15	.12	1.84	.45	.87	1.02	83	--------	--------	.81	.60	.33	.17	.11	.06	.02
1 day	.79	0	.15	.12	1.93	.36	.71	.79	84	--------	--------	--------	.56	.32	.17	.11	.06	.03
1 week	.45	.02	.14	.13	1.65	.23	.43	.45	83	--------	--------	--------	.42	.29	.17	.11	.07	.01
1 month	.35	.05	.14	--------	--------	.18	.33	.35	89	--------	--------	--------	--------	.29	.17	.10	.06	.05
1 season	.34	.05	.14	--------	--------	.11	.28	.34	92	--------	--------	--------	--------	.17	.12	.10	.08	.05
1 year	.18	.10	.14	--------	--------	.10	.14	.18	100	--------	--------	--------	--------	--------	--------	.10	--------	--------
Cincinnati:																		
5 minutes	.99	0	.03	.02	2.74	.84	.99	.88	83	.86	.68	.40	.19	.07	.03	.02	.01	0
1 hour	.55	0	.03	.03	2.25	.46	.48	.55	83	--------	.48	.32	.17	.07	.04	.02	.01	0
8 hours	.27	0	.03	.03	1.83	.14	.23	.27	84	--------	--------	.19	.12	.07	.04	.03	.02	.01
1 day	.14	0	.03	.03	1.57	.11	.11	.14	84	--------	--------	--------	.09	.06	.04	.03	.02	.01
1 week	.08	0	.03	.04	1.25	.06	.06	.08	83	--------	--------	--------	.06	.05	.04	.03	.02	.01
1 month	.06	.01	.03	--------	--------	.04	.06	.06	83	--------	--------	--------	--------	.05	.04	.03	.02	.01
1 season	.05	.01	.03	--------	--------	.04	.05	.05	83	--------	--------	--------	--------	.05	.04	.03	.02	.01
1 year	.04	.03	.03	--------	--------	.03	.03	.04	100	--------	--------	--------	--------	--------	--------	.03	--------	--------
Los Angeles:																		
5 minutes	.68	0	.02	.01	2.19	.24	.51	.68	59	.56	.38	.15	.08	.04	.02	.01	.01	0
1 hour	.29	0	.02	.01	2.07	.13	.19	.29	67	--------	.25	.13	.08	.04	.02	.01	.01	0
8 hours	.13	0	.02	.01	1.87	.08	.09	.13	71	--------	--------	.10	.07	.04	.02	02	.01	0
1 day	.10	0	.02	.01	1.83	.06	.07	.10	71	--------	--------	--------	.06	.04	.02	.02	.01	0
1 week	.07	0	.02	.02	1.47	.04	.04	.07	65	--------	--------	--------	.04	.03	.02	.02	.01	.01
1 month	.03	.01	.02	--------	--------	.03	.03	.02	64	--------	--------	--------	--------	.02	.02	.02	.01	.01
1 season	.02	.02	.02	--------	--------	.02	.02	.02	58	--------	--------	--------	--------	.02	.02	.02	.02	0
1 year	.02	.02	.02	--------	--------	.02	.02	--------	67	--------	--------	--------	--------	--------	--------	.02	--------	--------

Philadelphia:																		
5 minutes	1.25	0	.08	.05	2.39	1.25	1.05	1.00	76	1.18	.99	.75	.49	.21	.08	.04	.02	0
1 hour	1.03	0	.08	.05	2.31	1.03	.85	.84	76	--------	.85	.69	.47	.21	.08	.04	.02	0
8 hours	.58	0	.08	.06	2.01	.56	.58	.54	77	--------	--------	.54	.39	.19	.09	.05	.03	.01
1 day	.46	0	.08	.07	1.87	.35	.46	.43	78	--------	--------	--------	.31	.18	.10	.06	.03	.01
1 week	.20	0	.08	.07	1.47	.17	.20	.19	81	--------	--------	--------	.18	.15	.09	.08	.05	.02
1 month	.15	.02	.08	--------	--------	.13	.12	.15	86	--------	--------	--------	--------	.11	.09	.08	.06	.03
1 season	.14	.03	.08	--------	--------	.09	.08	.14	83	--------	--------	--------	--------	.09	.08	.08	.06	.03
1 year	.09	.06	.08	--------	--------	.09	.06	.09	100	--------	--------	--------	--------	--------	--------	.06	--------	--------
San Francisco:																		
5 minutes	.33	0	.01	.01	2.71	.16	.33	.26	64	.30	.18	.13	.07	.03	.01	.01	0	0
1 hour	.26	0	.01	.01	2.54	.11	.26	.16	64	--------	.16	.11	.07	.03	.01	.01	0	0
8 hours	.10	0	.01	.01	1.80	.06	.07	.10	65	--------	--------	.09	.06	.03	.02	.01	0	0
1 day	.08	0	.01	.02	1.66	.05	.05	.08	65	--------	--------	--------	.05	.03	.02	.01	0	0
1 week	.05	0	.01	.02	1.25	.02	.03	.05	67	--------	--------	--------	.03	.03	.02	.01	0	0
1 month	.03	0	.01	--------	--------	.01	.02	.03	75	--------	--------	--------	--------	.02	.01	.01	.01	0
1 season	.03	0	.01	--------	--------	--------	.01	.03	75	--------	--------	--------	--------	.03	.01	.01	.00	0
1 year	.02	.01	.01	--------	--------	--------	.01	.02	67	--------	--------	--------	--------	--------	--------	.01	--------	--------
Washington:																		
5 minutes	.87	0	.05	.04	2.05	.42	.56	.87	77	.68	.53	.38	.23	.11	.06	.03	.02	0
1 hour	.62	0	.05	.04	2.03	.38	.48	.62	77	--------	.48	.37	.22	.11	.06	.04	.02	0
8 hours	.35	0	.05	.04	1.77	.23	.35	.32	78	--------	--------	.26	.19	.11	.06	.04	.02	0.01
1 day	.25	0	.05	.04	1.78	.18	.25	.22	78	--------	--------	--------	.17	.11	.06	.04	.02	.01
1 week	.15	0	.05	.06	1.41	.15	.13	.13	78	--------	--------	--------	.13	.10	.07	.04	.02	.01
1 month	.11	.01	.05	--------	--------	.10	.11	.09	83	--------	--------	--------	--------	.10	.07	.04	.02	.01
1 season	.10	.01	.05	--------	--------	.10	.10	.06	92	--------	--------	--------	--------	.07	.06	.04	.02	.01
1 year	.05	.04	.05	--------	--------	.05	.05	.04	100	--------	--------	--------	--------	--------	--------	.04	--------	--------

[1] Measured by electroconductivity. Values may at times be greater or less than the true sulfur dioxide concentration.

TABLE 2.—*Threshold concentrations of sulfur dioxide, sulfuric acid, and their combinations, for various reflex responses (Bushtueva (13))*

Procedure used	Threshold concentration			
	H_2SO_4	SO_2	$H_2SO_4+SO_2$	
	μg/m³	ppm	μg/m³	ppm
Threshold concentration of irritation effects and odor perception	600–850	0.5–0.9	300	0.17
Data obtained by the method of eye adaptation to darkness	630–730	.31	300	.17
Data obtained by the method of optical chronaxy	730	.50	600	.40
Encephalographic method	630	.30	300	.17
"Electrocortical" conditioned reflex	400	.20	150 300	.17 .08

REFERENCES

1. Patty, F. A., (ed.) Industrial hygiene and toxicology. Vol. II. Toxicology. Fassett, D. W. and Irish, D. D., eds. Interscience Pub. Inc., New York, 1963. pp. 831–2377.
2. Dubrovskaya, F. I. Hygienic evaluation of pollution of atmospheric air of a large city with sulfur dioxide gas. In: Limits of Allowable Concentrations of Atmospheric Pollutants. Book 3. Ryazanov, V. A., ed. Levine, B. S., trans. U.S. Dept. of Commerce. OTS. Washington, D.C. 1957. pp. 37–51.
3. Bushtueva, K.A., Polezhaev, E. F. and Semenenko, A. D. Electroencephalographic determination of threshold reflex effect of atmospheric pollutants. Gig. i Sanit. 25:57–61. 1960. In: U.S.S.R. Literature on Air Pollution and Related Occupational Diseases. A Survey. Vol. 7. Levine, B. S., trans. and ed. U.S. Dept. of Commerce. OTS. Washington, D.C., 1962. pp. 137–142.
4. Amdur, M. O., Melvin, W. W. and Drinker, P. Effects on inhalation of sulphur dioxide by man. Lancet 2:758–759. October 10, 1953.
5. Tomono, Y. Effects of SO_2 on human pulmonary functions. Japan J. Ind. Health 3:77–85. February 1961.
6. Lawther, P. J. Effects of inhalation of sulphur dioxide on respiration and pulse-rate in normal subjects. Lancet 269:745–748. October 8, 1955.
7. Nadel, J. A., Tierney, D. F. and Comroe, J. H. Pulmonary responses to aerosoles, Proc. 3rd Air Poll. Med. Res. Conf. Calif. State Dept. Pub. Health, Los Angeles, Calif. December 9, 1959. pp. 66–74.
8. Larsen, R. I., Zimmer, C. E., Lynn, D. A. and Blemel, K. G. Analyzing air pollutant concentration and dosage data. J. APCA 17:85–93. February, 1967.
9. Amdur, M. O. Respiratory absorption data and SO_2 dose-response curves. Arch. Environ. Health 12:729–732. June 1966.
10. Toyama, T. Studies on aerosol. I. Synergistic response of the pulmonary airway resistance on inhaling sodium chloride aerosols and SO_2 in man. Japan J. Ind. Health 4:86–92. 1962.
11. Nakamura, K. Response of pulmonary air-way resistance by interaction of aerosols and gases in different physical and chemical nature. Japan J. Hyg. 19:322–333. December 1964.
12. Amdur, M. O. and Corn M. The irritant potency of zinc ammonium sulfate of different particle sizes. Am. Ind. Hyg. Associ. J. 24:326–333. July–August 1963.
13. Bushtueva, K. A. New studies of the effect of sulfur dioxide and of sulfuric acid aerosol on reflex activity of man. In: Limits of Allowable concentrations of Atmospheric Pollutants. Book 5. Ryazanov, V. A., ed. Levine, B. S., trans. U.S. Dept. of Commerce. OTS. Washington, D.C. March 1962. pp. 86–92.
14. Spicer, W. S., Reinke, W. A. and Kerr, D. H. Effects of environment upon respiratory function II. Daily studies in patients with chronic obstructive lung disease. Arch. Environ. Health 13:753–762. December 1966.

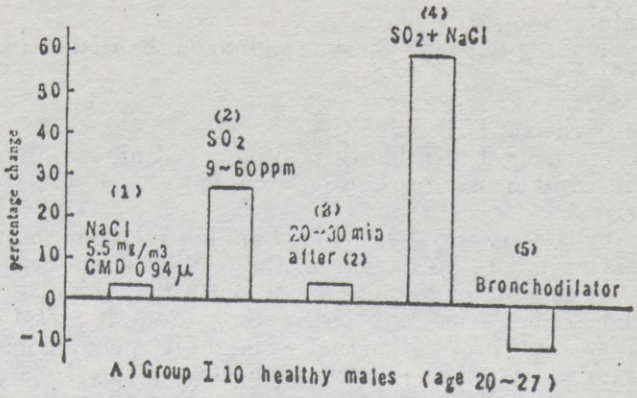


Fig. 1. The average percentage change of airway resistance after gas and aerosol inhalation (control value 0). Copied from Reference 11.

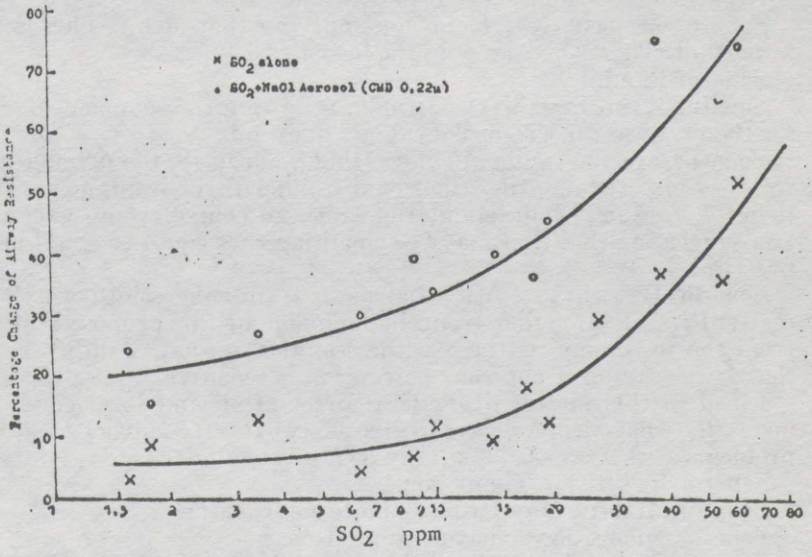


Fig. 2. Dose-response relationship in percentage change of airway resistance after inhalation of SO_2 plus aerosols. Copied from Reference 10.

Senator SPONG. Mr. Chairman.

You are also preparing a memorandum on the British paper; is that correct?

Mr. WILLIAMS. Yes, sir.

Senator SPONG. To be submitted.

Mr. WILLIAMS. I mention this, in part, because a while ago we did not give a full answer to your question, but we are preparing such an answer.

Senator BAKER. May I say this: I am not trying to unduly prolong this hearing nor to go too far in the technical ramifications of this thing, but as Senator Spong pointed out after we had the testimony from our friends from England it seems to me it raised at least the possibility of the proposition that we might be spending many millions of dollars and in effect requiring industry to spend many hundreds of millions of dollars without knowing what effect we are going to have. I think I disagree with our friends from England.

Senator SPONG. I want to say to Senator Baker that so far as I am concerned he is not prolonging these hearings; he has contributed immeasurably to my education by his questions and I hope he will continue to question just as extensively.

Senator MUSKIE. If we wanted to shorten the hearings, we would not have invited Dr. Middleton back this morning.

Dr. MIDDLETON. I am sorry I speak so unclearly.

Senator MUSKIE. No; I am not implying that at all. This is very important. This is necessary to the hearings.

Senator Randolph.

Senator RANDOLPH. Mr. Chairman, following the comment of Senator Baker, I want to ask my colleague a question.

Senator, are you saying, in effect, that you can see the possible areas for two sets of standards, a national standard which might vary and then the local or specific standards which, of course, would vary? Are you suggesting that that may be something that could or could not be practical?

Senator BAKER. Yes, Mr. Chairman. I am suggesting two things, really. First, I infer that from the language of this proposed bill and from the testimony of these witnesses, and, second, I didn't realize that I was saying it but your perception is sensitive.

I feel in this matter of Federal preemption and local conditions no matter what we do we have to give effect to local conditions and local problems as they arise. This is my own personal view.

Senator RANDOLPH. Thank you.

Senator MUSKIE. May I ask two more questions?

Senator Spong, do you have any questions?

Senator SPONG. I await with interest the charts and the tables that you are preparing. I don't want to be facetious but I am afraid we may end up with a plant-by-plant rather than an industry-by-industry approach.

We have talked about the weather; we have talked about geography; we have talked about the distance of the plant from the people, and we might even get into the automobile situation in a particular area. I can see no end to it insofar as trying to establish anything that is objective.

I am going to reserve my opinion until I see what you come up with. Whether you gentlemen return or not, I would like to talk to you about your ideas of how these standards are to be enforced.

Dr. MIDDLETON. We look forward to that, Senator Spong. I shall enjoy discussing that with you.

Senator BAKER. Mr. Chairman, may I say one thing elaborating Senator Spong's report?

I think particularly in this plant-by-plant problem of the situation that was outlined to us by an official of the aluminum company. Private industry has no power of eminent domain. When we are speaking of this small radius of immediate primary effect, we might, if we are not careful, require industry to spend far in excess of the benefits. I think of going out and buying the mile around that plant to eliminate adverse effects on human organisms of these primariy emissions.

Alcoa did precisely that. They refer to it as a buffer zone.

I think if we are not careful we may get into the situation of having each plant in the United States meet emission levels and then requiring them to take certain measures which relate only to that plant and possibly precluding them from solving the problem by either putting it in a plant in a very remote area or buying a buffer area around it.

This is no conclusion on my part but it certainly admits of that possibility.

Senator SPONG. Mr. Chairman, I have no further questions.

Senator MUSKIE. I have two questions. I think, first of all, they can be answered fairly briefly.

Do the minimum standards mean that such standards may not require the full application of the available technology in a given industry?

Dr. MIDDLETON. In most cases it may and in some it may not. In those cases where control technology is so advanced that one can overcontrol more than to the level where there is an adverse effect on health and welfare—it may be possible.

Senator MUSKIE. For example, the witness of the steel industry the other day pointed out that in new steel plants they built in technology to control 95 percent of the particulates. There is available technology to control them 99, 98 percent.

Dr. MIDDLETON. Yes, sir.

Senator MUSKIE. Whether or not they try to achieve full application of technology depends upon their impressions of the ambient air quality in the given location.

Now, is it conceivable that the national standard applied to particular emissions from steel industries might permit 95 percent control rather than 99 percent control even though the technology is available for the latter?

Dr. MIDDLETON. It is conceivable.

Senator MUSKIE. If that is so, isn't that going to be based upon a variation in the impact upon the surrounding ambient air of the differing degrees of control?

Dr. MIDDLETON. It is possible that the ambient air situation may require more if, to use Senator Baker's remarks, it is added to the chemical reaction that is going on in that region. In fact, there may be need to have a further reduction. This is again relating to the discussion regarding the local effect versus the larger airshed regional air quality approach.

Senator MUSKIE. So here is another variant.

Dr. MIDDLETON. Yes, sir.

May I say——

Senator MUSKIE. One other question.

Dr. MIDDLETON. Pardon me, sir. Yes.

Senator MUSKIE. You made it clear the other day that a given industry may have different pollutants, each of which may be deleterious or not. You could have a national standard apply to one and not another of the pollutants from a given industry, is that not so?

Dr. MIDDLETON. At any one time it may be so until the knowledge is available to control them; yes, sir.

Senator MUSKIE. So what you are talking about really is not just an industry standard but a pollutant industry standard.

Dr. MIDDLETON. Yes; we try to separate those two points quite clearly.

We also are trying to point out that whereas you dealt in our conversation, particularly this morning, with the specific pollutant, let us be careful to remember that we are dealing with the total pollution burden of the air and its effect upon health and welfare.

It is the totality of pollution that concerns us—the scientist is largely constrained to study the individual gas or solid particle or liquid droplet because of the nature of his experimentation—but it is the mixture of the several things that is important and that is why we must continue with the epidemiological approach and not be complacently satisfied with the individual single gas or particle study.

We do not know as much as we must about the health effects of the mixture for it is the mixture that we breathe.

Senator MUSKIE. Now, one other question.

The national standard is based upon the concept of a single source polluter so that when a new plant is constructed in a given location it will have to meet the national standard.

Dr. MIDDLETON. Yes, sir.

Senator MUSKIE. Now, if the number of such sources is multiplied in that same location, presumably a higher standard might be required in that location; is that not so?

Dr. MIDDLETON. Yes, sir; multiplicity of sources.

Senator MUSKIE. As I understand your concept, the additional control required would then be a function of whatever local agency operated in the area.

Dr. MIDDLETON. Yes, sir.

Senator MUSKIE. It would seem to me that the company that built the first plant might feel that, having met the national standard, it had been given a license to emit in accordance with that standard and that it would be unreasonable for that plant to be subsequently required to add additional controls in accordance with the mandate of some local authority, it being obviously more expensive to add the additional controls once the plant has been constructed than it would have been to put in full control, especially if the technology was available when the plant was first built.

Dr. MIDDLETON. It perhaps would be industry that would feel this way. I am sure if there were a demonstration that further reductions were required that the response would be understood and responded to.

I think also the industry, in view of your comments earlier about the relative costs, percent increases in control, would like to anticipate this need as much as possible.

I think a further point needs to be mentioned and that is that the sooner national emission standards can be employed, the better industry will be because it is much cheaper to build a plant with these constraints than it is to have them added after the construction.

Senator MUSKIE. That raises another question that has been raised by industry testimony. They argued that the resources available in a given industry, however well off, are still limited and that they ought to apply those resources in the area where air pollution is the most severe; and that if they are required to apply national standards to all their plants wherever located they necessarily will be diverting some of the resources from the areas where they are most needed to areas where they are less needed.

How do you respond to that?

Dr. MIDDLETON. I hope they don't admit that there are no people around some of their plants.

Senator MUSKIE. I don't think that is quite responsive, Dr. Middleton.

Dr. MIDDLETON. I would prefer to be as responsive as I can.

I would say to control only to the extent that it is economically feasible is a different concept than the desire to provide for the protection of health and welfare.

Senator MUSKIE. But if you are a doctor and you go into a hospital with a lot of ill people and attend to those who are in the direst circumstances first—now we are talking here about plants that may be located in Death Valley or comparable situations having to meet the same standard as a plant in downtown Manhattan, for instance.

Where should the resources be applied first? Obviously, in Manhattan, even though there may eventually at some point be a problem in Death Valley. We are talking about priorities here and what the testimony argues, I think, is that a national standard eliminates the idea of priority in the application of industry resources.

Is this a valid comment, in your judgment?

Dr. MIDDLETON. I would say there is a compelling need to have national emission standards so that industry will recognize the nature of their pollutant and its possible adverse effects upon health and welfare and to allow them to route their resources to take care of those areas in which they have the greatest number of sources so that they can see that the total reduction takes place as promptly as possible.

This may speak to having a schedule of degrees of control which State and local governments wish to follow with regard to the ambient air quality.

Senator MUSKIE. Well, if you proclaim a national standard does this not involve a timetable for compliance?

Dr. MIDDLETON. It would.

Senator MUSKIE. Would the timetable vary more in one place than in another?

Dr. MIDDLETON. It would vary only in the sense that State and local governments may elect to have these standards or better ones.

Senator MUSKIE. I know, but the minimum standards would be applicable everywhere at the same time, would they not?

Dr. MIDDLETON. Yes.

Senator MUSKIE. And there is no flexibility here.

Dr. MIDDLETON. We have not conceded that.

Senator MUSKIE. So that your timetable for compliance will not take into account the availability of resources in a particular industry to meet the timetable on a priority basis.

Dr. MIDDLETON. Except as we have said that these would be promulgated only as the technology and the economic feasibility is demonstrated.

Senator MUSKIE. By economic feasibility, would you take into account actually going into the books of a company to determine whether or not it has sufficient reserves or credit or borrowing capacity to pay for the equipment? I doubt that you mean that.

Dr. MIDDLETON. No, sir. We mean that it would not cause an imposition on the company.

Senator MUSKIE. This is what I thought you meant.

Dr. MIDDLETON. That is what I do mean.

Senator MUSKIE. So that, you cannot take into account priorities that may be of necessity related to the availability of resources in a particular industry or company to meet a uniform national standard. It cannot, I don't think, from what you said. Am I correct?

Dr. MIDDLETON. I don't think it is the intent of the U.S. Public Health Service to really dictate financial policy in the company, but rather to point out how a company should be prepared to respond.

Senator MUSKIE. But since you cannot take it into account, might you not find yourself in the position of requiring a given company to do something that it hasn't the resources to do?

Dr. MIDDLETON. That is conceivable.

Senator BAKER. Could I ask two more brief questions?

Senator MUSKIE. Yes.

Senator BAKER. One statement I understood you to make, Dr. Middleton, gives me a rather basic concern.

Did I understand you to say we are not concerned with the economic feasibility of control measures but rather considerations of health and welfare?

Dr. MIDDLETON. No; not at all.

Senator BAKER. What is your statement?

Dr. MIDDLETON. My written testimony and my prior appearances have said—if I made an error this morning I will controvert it—I said that we would establish these national minimum standards based on criteria, as well as consider economic and technical feasibility.

Senator BAKER. Now the statement I recall you making relating to Chairman Muskie's remark about establishment of national emission standards and the question of the ability of a particular industry or a particular plant to implement these standards, I thought I understood your reply to be that your emphasis was on health and welfare standards and not on economic feasibility.

Now you say that was a misapprehension?

Dr. MIDDLETON. That was not the implication. I am sorry, sir.

Senator BAKER. Because, if we were involved in the purest, most abstract and most humane considerations of air purity, we would all be praised, I am sure, for that and would all agree with it except we also might destroy the Nation's economy if that were the sole criteria.

Dr. MIDDLETON. I think I may not have clarified that point sufficiently. To reemphasize, Senator Muskie, in the development of these emission standards, we would be working with those to be regulated so that there would be the best input of knowledge not only from the technical, but the other aspects, so that the community of interest may best be served.

Senator BAKER. Dr. Middleton, I thank you for that clarification.

As a matter of policy, from the overall form and shape of this proposed legislation according to your viewpoint and the administration's position, is the dispersal of pollution by contributing industry into other areas of the country an accepted way and a desired way of combating air pollution generally?

Specifically, would you look with favor and would you tend to try to encourage the removal of pollution plants from highly urbanized areas into more rural areas?

Dr. MIDDLETON. It is not our intent to disrupt the present patterns of industrial growth and urban expansion. It is our intent to protect the health and welfare of both of these communities.

Senator BAKER. All right, sir.

Let me ask the second question and see if that gets closer to what I am trying to find out.

Would the fair impact and the probable effect of the legislation proposed in your judgment be to accelerate the dispersal of industry?

Dr. MIDDLETON. I don't think so.

I could comment further but it would only be accenting the belief I have that this is not the case.

Senator BAKER. All right.

There would be differences in the levels of control of emissions in highly urban areas and in rural areas, would there not?

Dr. MIDDLETON. There may be; yes, depending upon this background we talked about earlier.

Senator BAKER. And almost inevitably there would be, would there not, Doctor?

Dr. MIDDLETON. This is not so much a moot point, but it seems to me the technology we are developing for control capabilities mitigates against this point. There is a movement of dispersal within industry to rural areas particularly in the power generating business, as Senator Randolph knows, such that there are now mine-mouth power developments. This is not coming about because of the need to force people from one area to another but just a better economic situation.

Senator BAKER. I am not implying that you are trying to force them, and believe me, I am not trying to lay a political or legislative trap for you, but this is my line of thinking.

If you have varying standards from area to area, depending on the area and type of problem and the number of people or receptors that are affected, it follows, it seems to me, inevitably that it will cost more to control emissions in a highly urbanized area than in a rural area.

If it costs more, the age-old law of economics indicates there will be a dispersal of industry into rural areas.

Dr. MIDDLETON. This is not only a belief on your part but that has been substantiated, I believe, by the development of power in the Los Angeles Basin.

Senator BAKER. Is this one of the anticipated purposes and remedies for urban air pollution that is implicit in this approach to this problem?

Dr. MIDDLETON. It is not an anticipated purpose; it may be a natural result.

Senator BAKER. All right, sir. Fine.

Senator MUSKIE. Well, I guess we will end on that note.

Dr. MIDDLETON. Thank you, sir.

Senator MUSKIE. Let me say, Dr. Middleton, I appreciate your coming. I didn't invite you for any purpose except to enlighten the subcommittee. I think the discussion has been very helpful to us.

We are going to try to write a constructive piece of legislation, and the form it will take at this point I could not say, but we do appreciate your coming. This is the third time you have come and you have enlightened us each time.

Dr. MIDDLETON. Thank you very much.

May we say how much we enjoy your asking us to come. Your interest and courage in carrying forward the all-important need to control and abate our serious national air pollution problem commands public support, and you and your subcommittee deserve credit for your efforts in this matter.

Senator MUSKIE. Thank you, sir.

At this point, I will submit in the record this statement. The Diversified Metals Corp. asked for an opportunity to testify. We were not able to include them in the list of witnesses, so the statement will be included in the record.

(The statement referred to follows:)

STATEMENT OF BEN FIXMAN, PRESIDENT, DIVERSIFIED METALS CORP.

Gentlemen, the purpose of my coming before you today is to describe how a relatively new process, commonly called the "cold" process, has had an important impact in solving this country's air pollution problems due to the burning of insulated wire.

This insulated wire is being burned by scrap dealers, wire mills and refineries throughout the United States. Most of these refineries are located in the New York-New Jersey and Pessnsylvania area. This area can be classed as critical in terms of pollution from industrial sources.

The "cold" process developed over the past five years by Diversified Metals Corporation, involves the recovery of copper and aluminum from electrical type wires, having plastic and rubber insulations. Diversified is a young St. Louis, Missouri firm with processing plants in that city and in Monrovia, California and Tamaqua, Pennsylvania.

These three locations have enabled Diversified Metals Corporation to service some of the country's insulated wire producing mills.

Our primary function is to recover copper and aluminum metals from all types of insulated electrical wire. The process is carried on mechanically, with the absence of heat. Since no heat is involved, there are no pollution factors which could add to the poison-laden air which we breathe.

Before the use of the "cold" process for removing metal from insulated wire, all of these materials were and are still being burned in open fields or in crude incinerators. In some cases, the incinerators have after-burners which re-burn the smoke emitted from insulated wire. But, please keep in mind that the majority of insulated wire contains polyvinyl chloride. In burning such materials, what would appear to be poison-free, colorless gas is actually a colorless poison gas, and included is a fine dust-like particle, commonly known as particulate matter.

The dust-like particle comes from the clay fillers used in making the insulation.

These coloress gases produced from burning insulation in an incinerator with an after-burner are not the answer to air pollution. Burning insulated wire in large metropolitan areas is a great factor in causing pollution. In fact, it is so important that the burning of wire in the larger metropolitan areas is virtually prohibited. The reason for this is that during the burning cycle, hydrochloric and phosgene gases are emitted. We are all aware of the use in World War I of chlorine and phosgene as poison gases.

Since most scrap wires are accumulated by scrap dealers, wire mills and utilities throughout the country, it is usually common to mix all types of insulations in a single bundle. As a result, when this bundle is burned, no one really knows which poison gases will be emitted. Such gases include not only phosgene and hydrochloric acid, but could include fluorine from the new teflon wires and it usually includes sulfurous type gases from rubber insulated wires.

Therefore, it can be expected that phosgene, hydrochloric acid, fluorine and sulfur dioxide will be the common by-products of burning insulated wire, whether it be in an incinerator or in open fields.

Alert local air pollution committees are aware of these facts and are slowly but surely enacting legislation prohibiting burning of insulated wires, but more specifically, of plastic insulated wires.

The recovery of copper and aluminum from insulated electrical wire is no small item, because thousands of tons are involved. We know this to be true because Diversified Metals Corporation processes approximately four thousand tons of these types of wire monthly. Since we handle approximately 10% of the total produced in the country, what happens to the other 90%? This means that approximately 90% of insulated wire scrap in this country is still being reclaimed by other methods, of which burning is the most harmful.

These thousands of tons of scrap are daily emitting the previously mentioned poison gases which are a major contributor to the increasing problem of air pollution. It becomes somewhat ironic that a cheaper, better and higher metal recovery method is available to the public, which at the same time eliminates contamination of the air we breathe. We feel it is unfortunate that although the method to prohibit air pollution from these items is available, it is not being used to a greater extent.

At this time, we have facilities to process a greater tonnage of the material now being burned and, I might add, at a lower cost than burning. We offer our facilities and our "know-how" to everyone using pollution generating methods.

Diversified Metals Corporation processes scrap wire for virtually all large wire mills. But as we must point out, this covers approximately 10% of the total nation's volume. The reason for this, of course, is that scrap wire produced through dismantling or replacement, from old cars, discarded wire, from electric utilities and so forth, all add up to a majority of the percentage of insulated wire scrap being burned today.

The amazing growth of our company in the past two or three years has been aided by civic and economic minded people who appreciate the value of receiving more money for their scrap wire, while at the same time, eliminating a potential public accusation of being a contributor to air pollution.

How short does our life become when gases of chlorine, sulfur dioxide, carbon monoxide, and so forth, are continuously inhaled by apparently increasing amounts, and what is the maximum amount we inhale before emphysema, lung cancer and bronchitis, shorten our life span?

The solution to burning wire has heretofore been prevailing winds, but what happens when the Donora, Pennsylvania, and London fog, and the New York City pollution-death episodes reoccur in ever increasing order?

In summation, gentlemen, we believe that Diversified Metals Corporation has contributed substantially to elimination of pollution created by the burning of insulated wire. This is because we mechanically return the plastic products in solid form, either back to the ground as land fill, or in reusable forms of molded plastic items. None of the metallics—and more importantly none of the vitally needed copper—is wasted or destroyed but is promptly reused in the form of alloys or virgin metals.

It is our opinion that the only way to quickly eliminate the burning of insulated wire in this country is for Congress to pass legislation specifically banning this practice.

As a civic minded company, we therefore pledge our support to such legislation, knowing it will eliminate the health hazards that the burning of insulated wire inflicts on the people of this country.

Senator MUSKIE. Our next witness is Mr. Charles F. Avila, president-elect, Edison Electric Institute, chairman of the Edison Electric Institute Division, and executive committee chairman of the board of Boston Edison Co.

STATEMENT OF CHARLES F. AVILA, PRESIDENT-ELECT, EDISON ELECTRIC INSTITUTE; CHAIRMAN, EDISON ELECTRIC INSTITUTE DIVISION; AND EXECUTIVE COMMITTEE CHAIRMAN OF THE BOARD OF BOSTON EDISON CO.; ACCOMPANIED BY T. T. FRANKENBERG, CONSULTING MECHANICAL ENGINEER FOR THE AMERICAN ELECTRIC POWER CO.; AND MAYNARD E. SMITH, LEADER OF THE METEOROLOGICAL GROUP OF THE BROOKHAVEN NATIONAL LABORATORY

Mr. AVILA. Thank you, Mr. Chairman.

My name is Charles F. Avila. I am chairman of the board and chief executive officer of Boston Edison Co., and president-elect of the Edison Electric Institute.

I also have served as chairman of the Electric Research Council since its formation in 1965.

I am appearing here today on behalf of the institute.

With me are Mr. T. T. Frankenberg, consulting mechanical engineer for the American Electric Power Co., who serves as chairman of one of Edison Electric Institute's committees concerned with problems of clean air; and Mr. Maynard Smith, leader of the meteorological group of the Brookhaven National Laboratory.

With your approval, I would like to make some brief introductory remarks and then call on Mr. Frankenberg and Mr. Smith to provide comments on the status of air pollution control technology which we believe will be of help to you.

The electric utility industry has been concerned with problems of emissions from steam powerplants since at least the turn of the century.

Until about a generation ago, "smoke" was considered the major problem in air pollution. Development of improved fuel-burning equipment and furnaces which could convert coal and oil to electricity more efficiently, leaving almost no unburned hydrocarbons, has done much to relieve the smoke problem.

As you know, much of emission coming from a powerplant today is simply condensation which evaporates harmlessly into the atmosphere.

You notice this particularly on very cold days when the vapor makes large clouds in the air.

The next step was "fly ash," the cinder discharge associated with both stoker and pulverized forms of coal firing. This problem was being discussed by technical committees within the industry in the early 1930's, and special equipment was developed to remove fly ash from furnace chimneys.

The electric utility industry has used 90 percent of the output of dust collector manufacturers, and efficiencies of over 90 percent are now the rule with values of up to 99.5 percent in some metropolitan areas.

While we are proud of what has been accomplished, we are aware that there is much more to do. We live in a society which requires more and more energy, and in which use of electric energy has been growing at about two and a half times the rate of total energy.

By the year 2000, we expect that about half the energy used in this country will be used to generate electric energy.

It might be well to note here that the electric utility industry is, in fact, a major contributor to improved air conditions. Think how black our skies would be if we depended on isolated furnaces, grates, small commercial boilers and small power and heat generators for our energy.

If this was the general rule for our energy, we would have pretty bad conditions.

A community that draws its energy from a highly efficient electric power system has made a very significant step in improving air quality. The rapid advance of electric house heating and the development of electric cars are major steps along this road.

As I testified before this subcommittee in March, our industry is deeply involved in research which we believe will lead to an economic electric vehicle in a very few years, and we are equally hopeful about the possibility of speeding the conversion of railroads to electric power.

We foresee greatly increased use of electric energy in years to come, and a changing mix in the fuels used to generate electricity. Studies made by the Edison Electric Institute indicate that by the year 2000 at least half of our electric energy supply will be generated from nuclear sources. This does not mean that the amount of coal, gas, and oil we use will decrease for the Nation as a whole.

On the contrary, use of these fuels will go up as our total use of energy goes up, although in areas that will benefit most from nuclear power the reverse will be true. But we do not see any lessening of our responsibility to meet the problem of stack emissions.

Last month, President Johnson announced his support for an increased level of research in the field of air pollution. We endorse the authorization increase, and we expect to continue our own research activities in this area.

Let me describe to you three of our current projects concerned specifically with sulfur oxides.

The first is an EEI project which has recently completed involving a study of the physiological effects of sulfur dioxide, sulfuric acid, fly ash, and other mixtures.

77-515 O—67—pt. 4——21

I have a copy of the report of the findings of this project which I will leave with the committee.

The second project I would like to mention is supported jointly by the Electric Research Council and the National Coal Association.

The primary objectives of this $4.3 million program are to determine the maximum concentration of sulfur oxide in the air at ground level that is compatible with good public health, and to find economically feasible means of controlling sulfur oxide emission from steam-electric power stations. The work done on this project is available to the committee as it progresses.

I might mention that this is the point you were discussing and attempt to define more precisely measurements of just what sulfur oxide does to the receptors because we feel that there is a great deal more to be learned in this area.

A third project which is to commence very soon, is jointly sponsored by EEI, the U.S. Public Health Service, the American Petroleum Institute, and Bituminous Coal Research, Inc.

Through it we hope to find what happens to sulfur dioxide after it leaves the stack and what reactions the compound undergoes as it is modified by sunlight and other chemicals in the atmosphere.

In addition to these and other EEI and Electric Research Council projects, individual electric utility companies are carrying on other work in this area.

My own company, for example, has employed Arthur D. Little, Inc., to determine whether there might be additional ways available to further reduce the discharge of pollutants from our stacks.

We have equipment at all our plants to sample flue gas, but no satisfactory equipment is available to continuously monitor the individual components of the flue gas. A. D. Little is working on this problem.

During the next few months we plan to begin testing several new methods of sulfur removal from stack gases.

I would like to point out in my area along the lines of this discussion a few moments ago, the winds prevailing are westerly and southwesterly. Our plants being on the ocean are on the eastern side of the city; therefore, most of this gas most of the time goes out to sea. So you can see there is a very special local situation there which would need quite different criteria or quite different requirements.

With this background, I would like to comment on two aspects of the legislation you are considering. As we understand it, S. 780 would introduce both industrywide and nationwide emission standards, and regional air quality commissions which, in fact, would probably be dominated by Federal representatives.

The consistent theme of these two provisions is that pollution of the atmosphere is a problem that can only be handled by the Federal Government.

We think pollution control is necessary, but we do not believe this is the best way to approach the problem.

The fact is that if we want to achieve a particular quality of ambient air, emission standards should vary from place to place in re-

sponse to local conditions. No matter what one's views may be as to whether the job of setting ambient air standards is a local, State, or Federal responsibility, the most economical way to achieve such a level would be to have emission standards which are not uniform and which reflect differences in weather conditions, other pollution sources, hours of operation, operating conditions, and stack heights.

If S. 780 is passed as now drafted, the Public Health Service will have one of two choices: Either it could tailor emission standards to reflect local conditions, which would require it to duplicate existing local pollution control mechanisms developed under the Clean Air Act, or it could simply set a nationwide standard sufficient to reach desired levels of ambient air quality for the worst location in the Nation.

This would impose unnecessary costs upon companies in other areas—costs which would ultimately be paid by the consumers.

The Clean Air Act was based on the belief that the technology of air pollution control makes it essentially a local, State, or regional problem. Efforts at these levels have been coupled with national action in research, compilation of data on effects of pollutants, and power to act on interstate situations where interstate compacts have not been effective. We believe this approach is sound and should be continued.

The effect of stringent national emission standards on the economy of a number of industries is a matter which I am sure has been discussed by this committee. It is a serious matter. Overly strict control regulations will impose unnecessary costs on the use of coal as a fuel. Nuclear energy and coal are close competitors in many areas of the country.

In New England, nuclear energy is more economical and we do not foresee coal in a major role in new electric generating plants in the area in the future.

However, more than half the coal mined in this country is sold to electric plants and most of coal's new business is in electric utilities.

The competition between coal and nuclear fuels has helped reduce the costs of electric energy to the consumer. It would be unfortunate to see coal priced out of many of its markets because of the need for uneconomic pollution control devices.

In summary, we believe nationwide and industrywide emission standards will not be an effective method of achieving the quality we all desire, and we believe that if regional commissions are established great care should be taken to see that they are not federally dominated.

Many in our industry are convinced that the use of high stacks provides an available technology that will go far toward solving the most immediate air pollution problems effectively and in an economically sound way.

Mr. Frankenberg represents this view. I will ask him to describe the status of this technology to you—and to give you some detail on the costs involved in the available alternatives.

Senator SPONG. I wanted to note what you had to say about the Clean Air Act.

I recall your testimony earlier about the electric automobile and I am glad to have you back here today. I want to say that I share your

view that local and State control would be desirable, but do you believe that the localities and the States have even begun to face up to the problem in the United States?

Mr. AVILA. I think that probably they have not and I think part of this is due to the fact that as yet we don't know enough about this problem to be too vicious in its control because you could upset the entire economy by rules you could make without really knowing in an engineering sense just what you were trying to accomplish, just how far you should go and how much you should spend to go that far.

I think you need to know much more about what it is all about than we do today. Of course, there is a great deal of work being done to try to determine these things.

Senator SPONG. Aside from the more sophisticated requirements, I am just speaking in terms of the more obvious sources of pollution.

Would you agree generally that in the United States, with the exception of metropolitan areas where there has been a crisis such as Los Angeles, New York City which has recently adopted a rather stringent program, and the cities of Chicago and Pittsburgh, that there has been very little local effort thus far in this direction and that under the Clear Air Act the States have done very little?

Do you agree with that statement?

Mr. AVILA. I cannot speak too much for the rest of the country on these particular activities.

In my own area, we check each new plant with our local authorities, discuss with them what they are going to do and frequently make changes in accordance with their desires before we build the plant.

Locally, therefore, I feel that there is effective control.

I suspect that there are probably areas where the economy would be badly hurt if they got too strict and possibly there they have not—maybe some of the mining towns, some of the smelters, but there they probably have not been as strict.

I don't know enough about those local conditions.

Senator SPONG. I wanted to say that I agree with the desirability of what you say but I do not believe that there is effective local control. I think the entire reason for this legislation is the failure for the most part of the States and the localities to respond to this legislation as it was originally enacted.

Mr. AVILA. I think I agree with you that we have a lot more to do.

Senator MUSKIE. Why don't you proceed, Mr. Frankenberg?

STATEMENT OF T. T. FRANKENBERG, CONSULTING MECHANICAL ENGINEER, AMERICAN ELECTRIC POWER CO.

Mr. FRANKENBERG. My name is Theodore T. Frankenberg. I am the consulting mechanical engineer of the American Electric Power System. I am also the chairman of the clean air subcommittee of the Edison Electric Institute. My appearance here today is on behalf of the institute. Biographic material is appended to my testimony.

Mr. Avila has given you a picture of the basic workings of the institute in regard to air pollution control.

Senator MUSKIE. Would you give us a list of the members for the record?

Mr. FRANKENBERG. I don't have it with me but we will make it available.

Also the actual operating cost during the year 1966. We believe that completed study will provide new light on the magnitude of the hidden costs that the electric utilities have been paying in an effort to be good neighbors in the community that they serve.

The second thing is the clean air subcommittee which took over from the old air pollution control subcommittee about 2 years ago. For other people in the industry, it serves as a reporting point for new legislation; it provides, as all the subcommittees of the institute do, a means for asking for data and to obtain this in a relatively short time from the member companies.

Thirdly, the Joint Electric Research Council and the National Coal Association. The first one of these was covered yesterday by Mr. Garvey, and the second one is mentioned by Mr. Avila. This is the work actually going on at this moment at Hazleton Research which is over at Falls Church, Va.

I would like to offer this committee a chance to visit these facilities and see what is being done.

The difference in this work to all previous work is that in previous work virtually no work was performed at the low levels actually experienced in town even under the worst conditions well along the normal ambient thing.

There have been in the past acute studies, 40, 50, 100 parts per million. This is to work in the levels, first in an upper level of about five parts per million and then down at 1.5 and point blank. These are the areas in which very much medical work is needed.

Incidentally, I should say that the absence of this work is one of the reasons that Dr. Middleton had a very difficult time with some of your questions, Senator.

That completes our story as far as the EEI is concerned.

Mr. Avila mentioned our conviction that companies can do a great deal to alleviate air pollution problems. This conviction is not a recent thing but one that we acted on and had documented 10 years before the passage of the Clean Air Act.

At the London meeting of the International Clean Air Congress in October 1966, Mr. Philip Sporn and I presented a paper dealing with our highly satisfactory experience with tall stacks.

In the interest of conserving time, I request permission to make that paper available as part of the record.

Senator MUSKIE. Yes; it will be made a part of the record. Is it very voluminous?

Mr. FRANKENBERG. No, sir.

Senator MUSKIE. All right.

It will be made part of the record.

(The paper and another exhibit submitted by Mr. Frankenberg are as follows:)

PIONEERING EXPERIENCE WITH HIGH STACKS ON THE OVEC AND AMERICAN ELECTRIC POWER SYSTEMS*

Philip Sporn** and T. T. Frankenberg† *United States of America*

The two OVEC plants with capacities of 1200 and 1000 MW were pioneering ventures in many ways. During their design stage, the ten largest thermal-electric plants operating in the United States had an average size of less than 600 MW. By 1963 there were 17 plants in operation, each exceeding 1000 MW.

The wind tunnel work and gas diffusion calculations leading to the selection of 683-foot stacks for the larger plant and 535-foot for the other is described. Dust-fall and SO_2 concentration studies in the field began prior to operation and continued for three years after full commissioning of the plants. Data obtained were used in evaluation of the diffusion equations, and to judge the correctness of certain mathematical models covering transient situations.

Experience obtained in operating and maintaining these pioneer stacks led to modifications in the design of the 825-foot stacks for Cardinal Plant near Brilliant, Ohio which will be commissioned in 1966.

1. Introduction

IN October 1952, the Ohio Valley Electric Corporation (OVEC) undertook the building of two very large plants to serve a new gaseous diffusion plant of the United States Atomic Energy Commission. These plants would be located on the Ohio River, one in south-eastern Ohio and the other near Madison, Indiana[1]. The net capacities were originally estimated to be 1,000,000 kW for the Ohio location and 1,200,000 kW at the Indiana site. In addition to the magnitude of these undertakings from the power supply viewpoint, each represented an especially difficult and challenging assignment from the standpoint of controlling air pollution. Due to their location and in consideration of the economic availability of coal that would, in general, be regarded as rather low quality, it could be foreseen that the plants might burn fuel containing as much as 4 per cent of sulphur.

The capacities of the ten largest plants operating in the United States in 1952 are shown in Figure 1, compared with the two projected plants. Due to the lower quality of coal that was dictated by the location of these new plants, they would discharge at least twice the amount of sulphur dioxide discharged by any previous plant. Further, their locations in predominantly rural areas insured that any inadequacies in the disposal of the flue gases would be glaringly apparent. Not only would these new plants be larger than any of their predecessors but the entire plant would be built at one time. Where plant additions follow one another, there is the advantage of moving into the following stages more gradually and thus incorporating those changes which appear to be desirable.

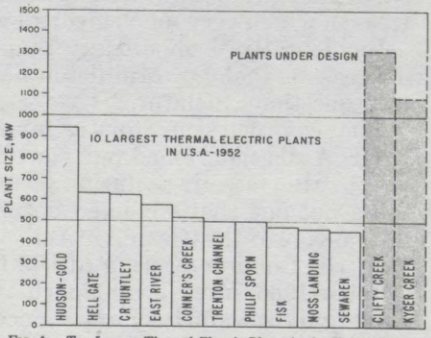


FIG. 1.—*Ten Largest Thermal-Electric Plants in the United States in 1952*

* An expanded version of Paper No. IV/9 presented at the International Clean Air Congress, London, 4-7 October, 1966.

** President, Ohio Valley Electric Corporation.

† Consulting Mechanical Engineer, American Electric Power Service Corporation.

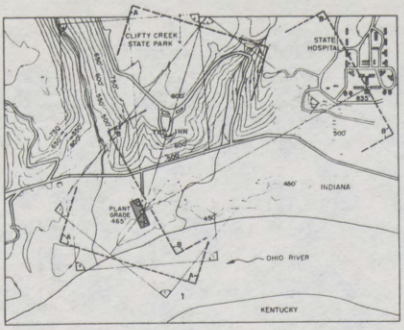


FIG. 2.—*Map of Clifty Area with Attention to Elevation and Wind Tunnel Areas A and B*

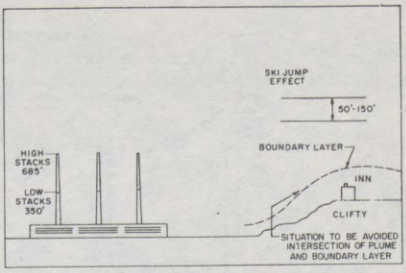


FIG. 3.—*Boundary Layer Effect and Added Rise Over the Hill*

In order to deliver the power in accordance with the Atomic Energy Commission's schedule, all design decisions had to be made without the benefit of any portion of the plant being completed. With this as the background, plans had to be developed to obtain the best information available, conduct wind tunnel and other studies, and to design the plant so that it would create a negligible or very minor effect on the ground level concentration of sulphur dioxide after reaching full load operation.

2. Planning

By November 1952, work had begun on collecting meteorological information concerning the two sites and arrangements were made to do wind tunnel studies of the site at Madison, Indiana, subsequently named Clifty Creek. The preliminary evaluation of this site indicated that from the standpoint of SO_2 it would present unusual difficulties. More careful studies carried out later, confirmed this. This was because, in the prevailing downwind direction from the plant, the flood plain is very short followed by an abrupt escarpment-like rise of the terrain to an elevation of approximately 350 feet above the plant grade. The plateau continues essentially unbroken for some twenty miles north and east of the plant. Situated on this high plateau, at its closest approach to the plant, there is a very popular state park with an inn located so that it directly overlooks the plant site. See Figure 2. On the same plateau, slightly further removed from the site, there is the South-Eastern Indiana State Hospital for mental patients. It was deemed absolutely imperative that highly concentrated stack plumes should not descend on either of these very sensitive areas of habitation under any foreseeable circumstances. In order to assure this, wind tunnel work was carried out at the University of Michigan which included the terrain shown in areas A and B of Figure 2. Two other areas shown were also modelled, but they proved to be less critical than the first two.

It was found that the stack plume would always come in contact with the slope of the escarpment and the level terrain beyond when the stack height was such that any portion of the plume intersected the boundary layer flow along the sharp rise to the plateau. If the stack height was chosen so that the plume would stay above this boundary layer, then a definite lift of the plume occurred as it passed over the rising area extending between the river flood plain and the plateau proper. This lift varied between 50 and 150 feet and provided a blanket of fresh air free from stack gases next to the ground and below the plume. Figure 3 shows both the boundary layer condition and the rise occurring with a higher stack. This was so obvious in the wind tunnel that an allowance of 50 feet was made for this "ski jump" effect when selecting the stack heights. At that time no effort was being made to include buoyancy effects in the wind tunnel study and the rise due to the dynamic effect of upward flow over the hillside was more apparent than it has been in more recent studies. From the wind tunnel studies, it was decided that any stack height above 650 feet would be adequate for the safe disposal of the stack effluent at Clifty Creek.

3. Theoretical Diffusion Calculations

Because of the need to know the ground level concentrations of SO_2 and the behaviour of the plume at distances well beyond those that could be modelled in the wind tunnel, gas diffusion studies were carried out. The Bosanquet, Carey, and Halton equation[2] was used to calculate a stack gas rise and thus determine the effective stack height. With the effective stack height calculated, the Sutton equation[3] was used to determine ground level concentration but with somewhat less conservative parameters.[1] Except for a few calculations by the American Electric Power's engineering staff, Irving A. Singer and Maynard E. Smith, Air Pollution and Meteorological Consultants, made all of the diffusion calculations for the stacks. Based on the wind tunnel observations all the diffusion calculations were made for an exit gas velocity of 120 feet per second.

To interpret the results of the gas diffusion calculations, it became necessary to make some choice of the limiting value of SO_2 that would be acceptable at ground level. No such limit was then, or has as yet been, authoritatively established in the United States. Considering the odour threshold value of two parts per million as the median level at which people sense the presence of SO_2, a safety factor of four was applied so that, for this purpose, the acceptable ground level concentration became 0·5 parts per million for a one hour period. The factor of four was chosen for the hourly mean value so that the peaks would normally stay below the odour threshold. Only strong wind conditions would produce values in excess of 0·5 ppm and such winds occur during a very small per centage of the total hours in the year. See Table 1. The normal variability of the wind would insure that the plume would not come over the same point on the ground very frequently. Thus, it can be seen that with regard to an entire year and to the whole terrain around the plant, the actual long term factor of safety was very much greater than four.

Although it was apparent from the wind tunnel studies that there would be an inflow of clean air over the ground at the beginning of the plateau, this could not be taken into consideration in the diffusion studies. Instead, calculation of concentrations on the high plateau lying north-east of the plant was done on the basis that the plain of the plateau projected until it intercepted the stack at its own elevation thereby reducing the effective stack height by 350 feet. This procedure also provides a certain factor of safety in regard to concentrations on the plateau since there may be more entrainment of air into the underside of the plume over the actual terrain than is calculated on the basis of this overly simplified mathematical model.

After careful consideration of all the data and with considerable

Table 1

TYPICAL AIRPORT DATA

CAA RECORDS PERIOD FEB. 1949 TO AUG. 1953 HOURLY OBSERVATIONS

Direction	*Total of all winds 4 mph and over % of year*	*% of all winds over 4 mph*	*Total of all winds between 13-24 mph % of year*	*% of time winds blow between 13-24 mph from each direction*	*Total of all winds between 25-31 mph % of year*	*% of time winds blow between 25-31 mph from each direction*
N	2·7	3·13	·2	·92		
NNE	3·5	4·07	·3	1·39		
NE	3·7	4·30	·2	·92		
ENE	2·6	3·02	·2	·92		
E	1·9	2·20	·2	·92		
ESE	2·7	3·13	·4	1·86		
SE	5·2	6·06	·7	3·26		
SSE	7·3	8·48	1·8	8 30	·1	8·3
S	7·3	8·48	1·6	7·35	·1	8·3
SSW	11·3	13·11	4·0	18·50	·4	33·4
SW	9·5	11·00	3·1	14·4	·2	16·7
WSW	8·3	9·65	3·5	16·3	·2	16·7
W	5·4	6·27	1·7	7·82	·1	8·3
WNW	6·4	7·44	2·1	9·68	·1	8·3
NW	4·5	5·24	·9	4·20		
NNW	3·8	4·42	·7	3·26		
Calm to	86·1	100·00	2·17	100·00	1·2	100·0
Less than 4 mph	13·9					
	100·0%					
% IN QUADRANT FROM SOUTH TO WEST		48%		64%		83%

concern for possible adverse conditions during the breakup of the nocturnal inversion, a stack height of 690 feet was chosen. A week following the decision, the stack height was reduced by 7 feet in order to secure the approval of the Federal Aviation Authority. Thus, the Clifty stacks were built to a height of 680 feet plus a 3-foot stainless steel cap, or a total effective height of 683 feet.

4. Kyger Creek Stacks

Having determined the stack heights for Clifty Creek on the basis of all the factors considered previously, it became a much easier matter to select a proper height for those at the smaller Kyger Creek Plant. Since there were no natural obstructions upwind from the plant, it was obvious that stacks conforming to the rule of "stack height equals 2½ times building height" would avoid aerodynamic downwash. No high land was located in the normal downwind quadrant closely enough to justify doing work in the wind tunnel. Such high land as there was, rose more gradually from the flood plain of the river and appeared less likely to be developed in the foreseeable future. Diffusion studies indicated that a height of 535 feet would provide acceptable conditions both in the valley and on the hills. Since there was no objection from aeronautical authorities, this was the height chosen.

5. Verification of Choice

Basic to the pioneering work on these two large plants was the decision to make the necessary effort to verify the design by testing for both SO_2 and dustfall prior to operation and for a substantial period after commissioning. Dustfall was monitored by means of twenty-four stations at Clifty Creek and sixteen at Kyger Creek. This work was done under the general supervision of the Battelle Memorial Institute and continued for three years after full load was reached. Dustfall studies were discontinued when it became abundantly clear that the plants had had no significant effect on this variable. Figure 4 shows the isopleths for a typical month after all units were in operation at Clifty Creek Plant.

In both the dustfall and the sulphur dioxide studies, special attention was paid to the areas north and east of each of the plants. This was done because the prevailing winds are generally from the south-west. Furthermore, as winds become stronger, the proportion from the south-westerly quadrant also increases.

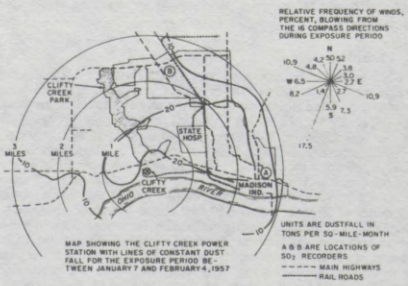


FIG. 4.—*Isopleths of Dustfall Around Clifty Creek Plant After All Units Were in Operation*

This is largely true over the entire area where the power plants of the American Electric Power System are situated, and has greatly simplified the location of test equipment. Table 1 shows the steady concentration of winds in this quadrant as velocity increases.

Three Leeds and Northrup Thomas Autometers were installed near each plant to obtain a continuous record of sulphur dioxide at or close to ground level. Figure 5 shows the general location of these recorders and the dustfall stations relative to Clifty Creek Plant and illustrates the way in which advantage was taken of the prevailing winds to concentrate the study within the area which was certain to be affected for the greater portion of the time. There are always special reasons for locating some sampling stations in areas infrequently swept by the gas plume. Such an area, the campus of Hanover College, lay directly west of Clifty Creek Plant, at a distance of approximately four miles, and this accounts for the four dustfall stations lying along a line drawn due west from this plant.

A careful review of the dustfall and the sulphur dioxide records was made late in 1959 after approximately four years of operation of both OVEC plants. This review showed no hourly mean concentrations above 1 ppm of sulphur dioxide for either

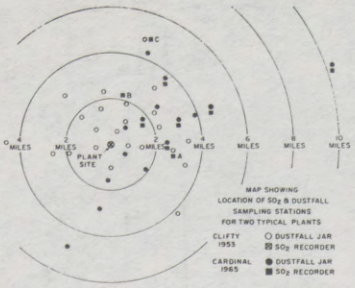


FIG. 5.—*Two Typical Sampling Layouts for Dustfall and SO_2 Stations*

plant. It was agreed that concentrations slightly above that level may occur infrequently on the plateau north of Clifty Creek Plant, with an occasional peak value just reaching the odour threshold. In general it was found that the original calculation of concentrations at both plants had given somewhat higher values than were actually experienced. This was explained as most probably due to:

(a) Enhancement of the plume rise by reason of the merging of the separate stack emissions.
(b) A slow rate of conversion of SO_2 in the plume to other compounds not measured by the recorders.
(c) Greater influx of clean air below the plume at the windward edge of the plateau at Clifty, which was not taken into account in the calculations.

One of the most gratifying findings was that the meteorological condition which had been expected to give rise to very severe problems, namely the breakup of night time inversions, with calculated concentrations of 5 to 10 ppm, failed completely to follow the mathematical model. This model, which had nothing to do with the Sutton equations, was based on the idea that the gas would all be confined to a narrow wedge of quite limited height below the inversion. Although there was a tendency for the recorded ground level concentrations of sulphur dioxide to occur during the mid-morning hours, there was not a single case of the very high concentrations typical of fumigations. These high stacks emitting large volumes of hot gases apparently achieve a greater degree of mixing than had been calculated. It is felt that gradual breakup of the inversion occurs due to the upper levels progressively becoming turbulent rather than by a distinct overturning movement with mixing confined to the boxed area beneath the plume. Whatever the mechanism, the results seem to indicate that the more restrictive ideas concerning the maximum size of thermal plants based on purely theoretical fumigation calculations[5] should be reviewed and considerably modified toward permitting larger aggregation of power generation equipment at a given site.

Tables 2 and 3 show that recording of any sulphur dioxide was an unusual event and that only the short term peaks approached the design values. These tables and other data from which they were derived, clearly establish the fact that these tall stacks completely eliminate ground level concentrations during inversions. Only a small proportion of the observed concentrations occurred at night when the inversions are normally present. When concentrations did occur at night, it was generally apparent from the winds, temperatures, or observations by the plant personnel, that no inversion was present. Thus, the inversion which is so often described as a "lid" holding down noxious gases, actually becomes a shield preventing the return of stack gases if they are first emitted at a reasonable height, with a reasonable velocity and at a reasonable temperature.

6. Developments Since Clifty and Kyger Plants

Several technical developments since 1952 have greatly improved the designer's ability to determine the probable results of various steps taken to control air pollution. One of these is a modification of the wind tunnel technique so that helium is added to get an equivalent buoyancy of the model plume corresponding to that of the hot gases leaving the stack. A tracer gas is also added. This technique is used with a high speed gas analyser connected to a probe which can be moved to any point of interest within the tunnel. This is a significant improvement over the visual observation and photographic records used for determining the path of the stack effluent on the Clifty Creek models.

Possibly of even greater importance is the development of digital computer programs to handle the tedious computations in the diffusion calculations. This has given the designer the opportunity to look at many more studies and thereby approach more closely the optimum condition. One of the early results of this ability to examine more cases was the discovery that exit gas velocity above 90 feet per second appeared to give very little improvement in ground level concentrations. In fact it was found that under some low wind speed conditions, the gas rise with 120 feet per second exit velocity was somewhat less than it would have been at 60 or 70 feet per second. This was due to the more rapid mixing occurring at the higher velocity with the resultant earlier loss of thermal buoyancy. While these are theoretical findings, they have influenced the choice of lower velocities on more recent stacks.

During 1962–1963, the Federal Power Commission sponsored a National Power Survey in the United States[6]. The purpose of this survey was to determine as nearly as possible the likely developments in the power industry within two periods: (a) during the decade ending in 1970, and (b) ten years later ending with 1980. Great interest focused on the probable size of units and the maximum size of plants for that period. In order to bring an informed judgement to bear on the part that air pollution might play in limiting plant size, the American Electric Power System sponsored diffusion calculations on power plants ranging from 300 MW to 8000 MW, with stack temperature of 200°F and 300°F and under four different wind velocities with their appropriate parameters for vertical stability, n, and for diffusion, Cy and Cz. Basically, these were wind velocities of 10, 20, 33 and 39 feet per second, but with an increase in velocity for extremely large plants. These studies looked at the range of stack heights from 200 to 1500 feet. The

Table 2. Clifty Creek Plant Results. Per cent of total hours when four or more units were in operation that any SO_2 was detected

Station	*Daylight Hours*			*Night Hours*		
*Gustiness Class**	*A*	*B*	*C*	*A*	*B*	*C*
B_2	0·6	0·2	0·2	—	—	—
B_1	1·9	0·6	0·4	0·3	0·1	0·3
C	0·5	0·4	0·5	0·2	0·1	0·1
Total	3·0	1·2	1·1	0·5	0·1	0·4

Table 3. Typical SO_2 concentrations as measured by Thomas Autometers, PPM

Gustiness	*Station A*		*Station B*		*Station C*	
Class	*Average*	*Peak*	*Average*	*Peak*	*Average*	*Peak*
B_2	0·10	0·40	0·10	0·25	0·05	0·20
B_1	0·10	0·40	0·07	0·30	0·10	0·25
C	0·05	0·20	0·10	0·40	0·10	0·40

* Brookhaven Gustiness Classification

	When Experienced	*Condition*	*Fluctuations of of Wind*
Class B_2	Principally during warm weather	Light winds, strong solar heating	Range from 45° to 90° horizontally
Class B_1	Average normal weather	Moderate winds, Moderate heating sunny to partly cloudy skies	Range from 15° to 45° horizontally
Class C	Frequently storm or pre-storm conditions	Strong winds, overcast skies	Not less than 15°

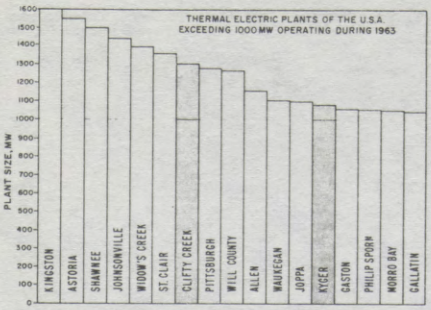


FIG. 6.—*Largest Power Plants Operating in 1963*

final report indicated that under favourable terrain conditions, there seemed to be no inherent air pollution limitation for power plants up to 5000 MW but that this size needed to be approached with caution based on much closer study of the large plants then coming into existence. By 1963, the number of very large plants in the United States appeared as in Figure 6, this shows that the pioneers of ten years before were reduced to seventh and thirteenth in a ranking based on size. The books of data resulting from this major computer study have been of great value in making preliminary estimates of existing plants and studies for new ones.

An unexpected development in regard to very high stacks occurred between 1960 and 1963, at which time a number of such stacks experienced problems of sulphation of the concrete. Some of these, but not all, were stacks with exit gas velocities high enough to produce positive pressure throughout their entire heights. This resulted in at least one stack being given a complete steel inner liner, and in the three Clifty Creek stacks having portions of the brick linings removed and replaced with gunite concrete over a steel road-mesh for that portion of the chimney which had a wall thickness less than ten inches. Both of these repairs appear fully adequate at this time. Most tall stacks now being built have some form of inner liner, either a free standing brick, a separate concrete liner or an independent steel lining.

The most recent arrangement on the American Electric Power System consists of a steel liner fashioned as shown in Figure 7. The "bazooka liner" was developed to provide a low loss entrance from the breeching, an approximate 20 per cent savings in plate and insulation costs up the long run of the stack, and a low exit loss at the top of the stack. Exit velocities are now selected between 60 and 90 feet per second based on a clearer understanding of the effect that this parameter has on ground level concentrations. Support of the insulated steel liner by suspender links avoids the necessity for heavy steel beams across the rather large diameter of the stack near its base. Since the liner is installed after the concrete shell is complete, and is top supported until the links are attached as the last step, there is much greater freedom of access than if the beam type of support were used. Access to the space between the liner and shell and the use of retractable fixtures permits replacing the aircraft warning lights except those at the very top, without leaving the interior space.

Advantage was taken of the relatively small diameter section of the stack liner to establish a sampling point for testing the electrostatic dust collector where meaningful results should be obtained by traversing the upward flowing gas. The shape of the liner permits an adequate circular platform to be built in the stack for handling the necessary probes and other equipment. The sampling point is sufficiently above the last restriction so that flow should be free of nonuniform turbulence.

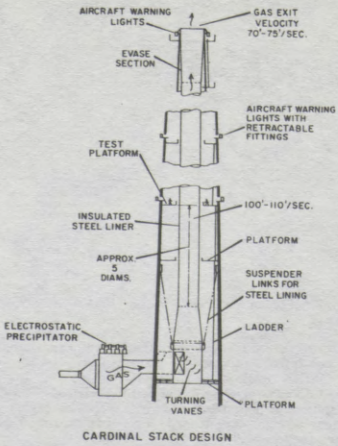


FIG. 7.—*Cardinal Stack Design*

7. Cardinal Stacks

The design of the stacks for Cardinal Plant which will have a total generation on one site of approximately 2100-2300 MW represents, in many ways, the culmination of all of the information, design and operating experience obtained since the building of Clifty and Kyger Plants. A map of the terrain surrounding the Cardinal Plant, Figure 8, shows areas A and B that were modelled for wind tunnel studies. The prevailing winds are essentially those shown in Table 1, so that area A contains the towns of Brilliant, Ohio and Wellsburg, West Virginia, while area B consists largely of the high land on the West Virginia side of the river. The similarity of this terrain to that at Clifty is shown on Figure 9. Here again, the plant is upwind of a substantial plateau but this plateau is broken by major and minor streams in a highly irregular fashion. Upwind from the plant, the terrain included a substantial hill but it was found that this had little effect on the plume rise if the stacks were high enough to protect the valley. The real area of interest lay beyond the end of the working section of the tunnel when the model was constructed at a scale of 600 to 1. At that time, this was thought to be the greatest reduction that could be made and still obtain dependable results. However, since then, some studies have been made for a future plant at a scale of 900 to 1 which is presently believed to be about the limit for this work.

The regions to be protected most carefully in this case were the inhabited areas in the valley at both Brilliant, Ohio and Wellsburg, West Virginia and the high ground along Route 27 east of Wellsburg extending to about Avella, Pennsylvania. The wind tunnel studies indicated that the valley areas could be protected with stacks 600 feet high, and the plateau by stacks of 800–900 feet.

As in the earlier case, gas diffusion studies were relied upon to determine probable ground level concentrations beyond the limits of the wind tunnel work. These studies began using 5 per cent sulphur in the coal to be burned, but it was found necessary to restrict this to 3·5 per cent in order to arrive at stacks of a reasonable height.

After considering all factors, a stack height of 825 feet above grade was selected. This was based on many considerations, among which were the following:

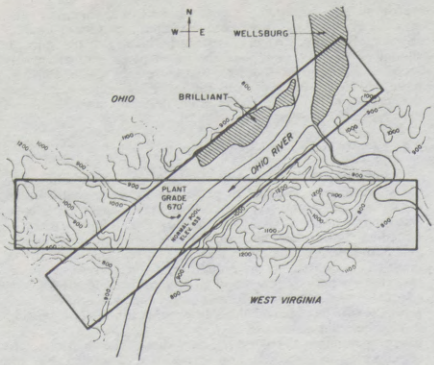


FIG. 8.—*Map of Cardinal Area with Elevations and Wind Tunnel Areas A and B*

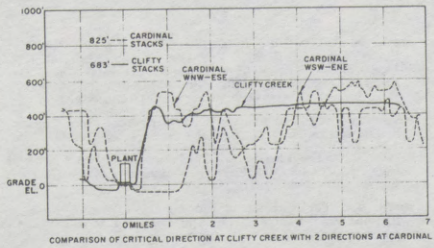


FIG. 9.—*Comparison of Profile for Clifty and Cardinal*

(a) It was decided that this height represented the maximum reasonable limit to which the existing technology of stack construction could be reliably extrapolated.

(b) The combining of the flue gases from two or more units into a single stack would be beneficial from an air pollution viewpoint and was contemplated. However, the experience with stack repairs at Clifty Creek argues against such a choice. As it is, a single unit per stack represents approximately a 50 per cent extrapolation in capacity beyond the Clifty Creek stacks.
Also since more restrictive regulations covering SO_2 emissions may be instituted under the Clean Air Act of 1963, it is possible that the third unit might have to have a higher stack than was selected at this time.

(c) Since only two units of the total plant development were to be built at this time, it seemed certain that there would be a period of not less than five years operation of these units before decisions were required concerning the third stack. This period of operation and observation would permit an exact evaluation of the plant's effect upon the SO_2 concentrations in the surrounding countryside.

As at Clifty Creek, arrangements were made for establishing a network of dustfall stations, sixteen in all, and six SO_2 monitoring stations. These have been shown on Figure 5 in which their locations are compared with the similar equipment at Clifty Creek. It is noticeable from this figure that the planning now includes areas considerably further from the plant than was the case 10 or 12 years earlier. A wind speed and direction indicator was installed on a transmission line tower located on the high bluff opposite the plant in order to obtain satisfactory wind records for correlation with both the dustfall results and the SO_2 records. Temperature will be carefully measured approximately 100 feet above the rim of the valley and also at ground level adjacent to the plant, in order to have more certain knowledge concerning the lapse rate. It is believed that the study carried out at this site may result in obtaining some worthwhile data for the correlation of diffusion calculations for hilly country with the observed results.

Unlike Clifty, Cardinal is located along a fairly heavily industrialized section of the Ohio River, which includes several steel plants, coke and chemical plants and two other power plants within an eight mile radius of its site. While it is too early to have any significant comment on the pre-operating SO_2 levels, it has been noticed that SO_2 readings tend to occur in the morning hours even at the station that is slightly more than ten miles from the plant. In general, these readings have been quite low, on the order of 0·05 to 0·20 ppm, and seem to be reflecting the same sort of breakup of the nocturnal inversion as was seen at Clifty Creek, but in this case from a widely distributed number of sources rather than from a point source. Considerable bituminous coal is still burned in this area for household heating and it appears certain that this will add to the complexity of our study at several of the SO_2 monitoring stations.

8. Summary—High Stacks

Over the past fourteen years, there has been an accelerating trend in the United States to demand improved conditions in the ambient air. Long before this, many of the electric utilities were doing a great deal to improve the situation, and are presently doing much more than the general public has been giving them credit for. Improved dust collectors have been installed and stack heights have been increased on many plants years before the problem had become disputatious.

It has become apparent that high stacks offer the only presently available pragmatic solution to the problem of disposing of SO_2. Studies of the problem of removing sulphur from the fuel before burning it have, so far, proved unavailing. Numerous studies seeking to remove SO_2 from the flue gas have arrived at estimated increases in cost of fuel, the effect of which makes the process completely unacceptable even before the operating problems have been evaluated by actual construction and operation. Because there may be a finite limit to the amount of SO_2 that can be diffused into the upper atmosphere, it is possible that high stacks can be accepted only as an interim solution to this problem, but presently they are the only solution available, and for a long time ahead, the diffusion limit will not be a problem. Since this is the case, there is a great need for more careful study before and after the installation of every major power plant having high stacks. This would permit a more extensive evaluation of the diffusion equations somewhat along the lines that have been started by the Tennessee Valley Authority[7]. Such studies, if carried to their logical conclusion, would provide the designer with a degree of confidence in evaluating the disposal of SO_2 that he does not possess at the present time.

9. The Coming Era of 2500–4000 MW Plants and SO_2 Problems

9.1. *The General Solution*

The era of 2500–4000 MW steam electric plant is not a fact that needs to be anticipated—it is here. Mention has been made of Cardinal. Within recent months, announcement was made of a new generating station to be located in the American Electric Power System in West Virginia with an initial installation of two 800 MW units and with a third unit to be installed sometime after 1971. The most likely size of this third unit will be 1050 MW. It is currently difficult to visualize an end to the trend toward larger units before reaching a unit size in the range of 1250–1335 MW. Thus, for coal burning plants, we are confronted with the need to critically examine the problem that a plant designer will be called upon to solve—to harmlessly dispose of 1250 tons of sulphur per day or 100 tons per hour

when converted into oxides of sulphur, mainly SO_3.

The authors believe that this offers no occasion for fear or dismay. Indeed, as fore-established, the high stack properly designed can, without question, take care of every requirement —ecological, economic, and esthetic. There are, however, a number of special areas of concern in connection with the adoption of this solution that warrant further, even if only brief, discussion, These follow:

9.2. *The Multi-Compartmented, Integrated Stack*

So far, in the United States, the single stack with multiple liners pioneered in England by the Central Electric Generating Board has not been used. Such stacks have many advantages from the standpoint of obtaining the maximum rise of the hot gas, the increase in the plume's ability to pierce inversions and the maintenance of reasonable exit velocity when one or more units is shut down. Offsetting these recognized advantages, are the costs associated with the poor utilization of the cross section of the stack, the question of ability to work on and around an idle liner while the other two or three are in use, and finally, the significant cost of bringing the effluent gases across considerable horizontal distances from several units in order to reach a stack of this type. It appears likely that several years may elapse before the combined effect of the greater need for such construction and bringing under better control some of the costs just mentioned, will permit the use of this type of stack in the United States.

9.3. *The Problem of Height, Material, Construction and Maintenance*

In applying very high stacks, a considerable problem with the aeronautical authorities must be faced. This is somewhat mitigated by the fact that it is already recognized that perhaps in level terrain, heights beyond 800 or 900 feet do not significantly improve the ground level concentrations. However, in hilly country, such as the terrain in which the plants described are located it is conceivable that stacks as much as 1200 or 1500 feet in height may ultimately be required. It has recently been announced that stacks of 1000 feet will be required on a new plant to be located in western Pennsylvania.

Stack design has undergone more rapid change in the past ten or twelve years than at any time since the power industry's beginning. New materials have been tried; different construction techniques utilized, and new problems have been faced. One of the continuing problems with very high stacks is to find responsible people who will undertake personal observation of the construction, inspection, and maintenance functions. Presumably, this may become simpler as very high stacks become more and more commonplace.

While currently, the stack consisting of a reinforced concrete shell having a low-alloy, corrosion resistant steel (such as Corten) liner, appears to be adequate after approximately six years' service, it would obviously be desirable to have double or triple this experience before concluding that it is the optimum solution. This construction appears to have one clear advantage which is that the two functions, structural integrity and impermeability to gas, have been separated completely. Thus, if any corrosive attack occurs later in the history of the stack, it should be possible to replace the metal plates without in any way being concerned about the structure as a whole. Furthermore, the accessibility of both the inner and outer surfaces of the shell should insure that no form of deterioration will proceed very far without being detected.

9.4. *The Monitoring and Building up of Technological History*

The fortunate development of the high stack as a solution to the sulphur dioxide problem presented by large coal burning plants was carried out on the basis of very meagre experience. But for the future it is most important that this deficiency be remedied. The authors most earnestly recommend, therefore, as new high stacks are designed and constructed, that an effort be made to obtain data on the ground level concentrations of SO_2 for extensive periods before and after operation. Needless to say, adequate meteorological information for the evaluation of these results should be obtained either from other sources or by special instrumentation at the site.

Every generation's engineers have been the heirs to the ingenious work, records and experience compiled by and transmitted to them by their professional forebears. Air pollution represents an area in which today's engineers must in turn develop such necessary data and make it available to the generations that will follow.

References

[1] SPORN, P. and MARQUIS, V. M. The OVEC Project: Economic, Engineering and Finance Problems of the 2,200,000 KW, 18,000,000,000 Kilowatt-Hour Power Project of the Ohio Valley Electric Corporation. AIEE Annual Meeting N.Y.C.—1954, Paper No. 54-57. Also presented at CEGRE Meeting, 1954.

[2] BOSANQUET, CAREY and HALTON. Dust Deposition From Chimney Stacks. Institution of Mechanical Engineers, pp. 355-367, 1950.

[3] SUTTON, O. G. The Theoretical Distribution of Airborne Pollution from Factory Chimneys. Royal Meteorological Society, *Quarterly* Journal, **73**: 426-435 1947.

[4] SMITH, M. E. The Varirtion of Effluent Concentrations From an Elevated Point Source. *Archives of Industrial Health*, Vol. 14. pp 56-68, July 1956.

[5] POOLER, F. Potential Dispersion of Plumes From Large Power Plants. Environmental Health Series. U.S. Public Health Service—*Publication No. 999-AP-16 1965.*

[6] National Power Survey, Part I, p 141-146 and Part II, p 55 Federal Power Commission, October 1964. U.S. Government Printing Office.

[7] GARTRELL, F. E. Monitoring of SO_2 in the Vicinity of Coal-Fired Power Plants—TVA Experience. *Proceedings American Power Conference XXVII* 1965.

High Stacks for the Diffusion of Sulfur Dioxide and Other Gases Emitted by Electric Power Plants

By T. T. Frankenberg, Consulting Mechanical Engineer, American Electric Power Service Corp., New York, N.Y.

In these days of multi-disciplinary activities, heart-lung machines, and replacement valves for the human heart, it may not seem strange that a mechanical engineer should be invited to appear on your program. Indeed, the eight months since this paper was offered have seen a number of developments which require those with an engineering background to speak out to the widest audience they can command. These developments come to mind immediately:

a. Efforts to clean up governmental sources of air pollution.

b. Issuing of the Sulfur Oxide Criteria.

c. The Vienna, West Virginia, Abatement Conference on March 22 and 23, 1967.

These otherwise rather diverse activities have two themes that run through them and bind them together. The first theme is the emphasis on SO_2 as a pollutant, in spite of the fact that the English and Europeans in general take a much more relaxed attitude toward this gas. The second theme is the insistence on reducing the sulfur content of the fuel, while ignoring the very major role that the tall stack can play in reducing the ground level concentration of SO_2 and all other gases emitted as a result of the combustion of fuel.

One of the six references cited at the end of this paper covers the theory of what can be expected of high stacks in lowering the ground level concentrations of gaseous pollutants. More important, the other five papers which have all been given in the past two years, cite the practical experience and proven benefits derived from the use of high stacks. These five papers not only show that the theory works, but that the measured concentrations are generally lower than those predicted.

The purpose of this paper is to briefly set forth the experience of one company in utilizing tall stacks. Late in 1952, the Ohio Valley Electric Corporation undertook the design and construction of two exceptionaly large power plants to serve a new load of the Atomic Energy Commission in southern Ohio. Figure 1 compares the two new plants, Clifty Creek and Kyger Creek with the

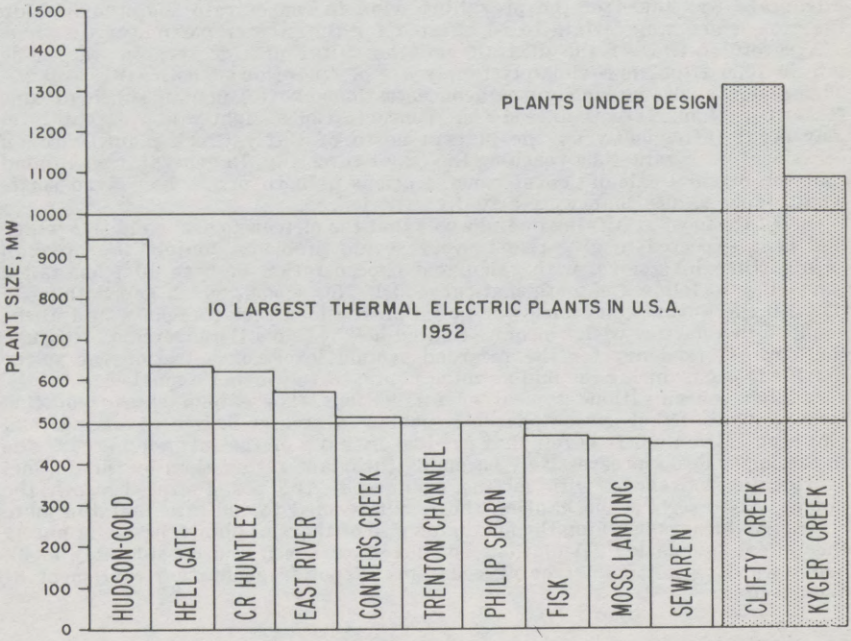


Figure 1

largest plants then in operation. Due to the characteristics of the coal to be burned, it was quite probable that either one of these plants would discharge at least twice as much sulfur dioxide as any previous plant. Since both of the new plants were located in predominately rural areas, any inadequacies in the disposal of flue gases would be glaringly apparent.

To insure proper stack height, both wind tunnel studies and gaseous diffusion calculations were undertaken for Clifty Creek Plant, since its terrain was considerably more difficult than that at Kyger Creek. The greatest problem at Clifty was to insure the plume would pass over a state park on a hillside quite close to the plant, as shown on Figure 2. Wind tunnel work showed that stacks 650 feet high with a gas exit velocity of 120 feet per second would be adequate. Gaseous diffusion calculations, however, indicated that a height of about 700 feet would be required to prevent the plume from striking the plateau under some wind conditions. After discussion with the Federal Aviation Authority, a final height of 683 feet was determined to be the best selection in view of certain conflicting requirements. During the wind tunnel studies it was observed that if the stack plume intercepted the boundary layer flow along the hillside, it was immediately pulled to the ground. However, if this layer of turbulent air was avoided by using higher stacks then the plume height was increased by from 50 to 150 feet as it passed over the hill.

Kyger Creek Plant had no special problems with terrain. The stack height of 535 feet was selected principally as a result of the gaseous diffusion calculations.

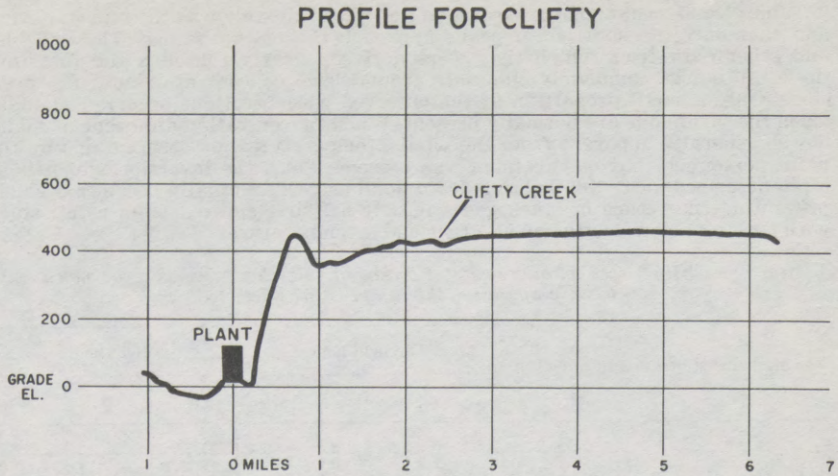
Basic to the pioneering work on these two large plants was a decision to make the necessary effort to verify the design by testing for both SO_2 and dustfall prior to operation and for a substantial period after commissioning. Dustfall was monitored by means of twenty-four stations at Clifty Creek and sixteen at Kyger Creek. This work was done under the general supervision of the Battelle Memorial Institute and continued for three years after full load was reached. Dustfall studies were discontinued when it became abundantly clear that the plants had no significant effect on this variable.

In both the dustfall and the sulfur dioxide studies, special attention was paid to the areas north and east of each of the plants. This was done because the prevailing winds are generally from the south-west. Furthermore, as winds become stronger, the proportion from the south-westerly quadrant also increases.

Three Leeds and Northrup Thomas autometers were installed near each plant to obtain a continuous record of sulfur dioxide at or close to ground level. Advantage was taken of the prevailing wind to concentrate the study within the area which was certain to be affected for the greater portion of the time.

A careful review of the dustfall and the sulfur dioxide records was made late in 1959 after approximately four years of operation of both OVEC plants. This review shows no hourly mean concentrations above 1 ppm of sulfur dioxide for either plant. It was agreed that concentrations slightly above that level may occur infrequently on the plateau north of Clifty Creek plant, with an occasional peak value just reaching the odour threshold. In general it was found that the original calculation of concentrations at both plants had given somewhat higher values than were actually experienced.

One of the most gratifying findings was that the meteorological condition which had been expected to give rise to very severe problems, mainly the breakup of nighttime inversions, with calculated concentration of 5 to 10 ppm, failed completely to follow the mathematical model. This model, which had nothing to do with the Sutton equations, was based on the idea that the gas would all be confined to a narrow wedge of quite limited height below the inversion. Although there was a tendency for the recorded ground level concentrations of sulfur dioxide to occur during the mid-morning hours, there was not a single case of the very high concentrations typical of fumigations. These high stacks emitting large volumes of hot gases apparently achieve a greater degree of mixing than had been calculated. It is felt that gradual breakup of the inversion occurs due to the upper levels progressively becoming turbulant rather than by the distinct overturning movement with mixing confined to the boxed area beneath the plume. Whatever the mechanism, the result seemed to indicate that the more restrictive ideas concerning the maximum size of thermal plants, based on purely theoretical fumigation calculations, should be reviewed and considerably modified toward permitting larger aggregations of power generation equipment at a given site.



BOUNDARY LAYER EFFECT AND ADDED RISE OVER THE HILL

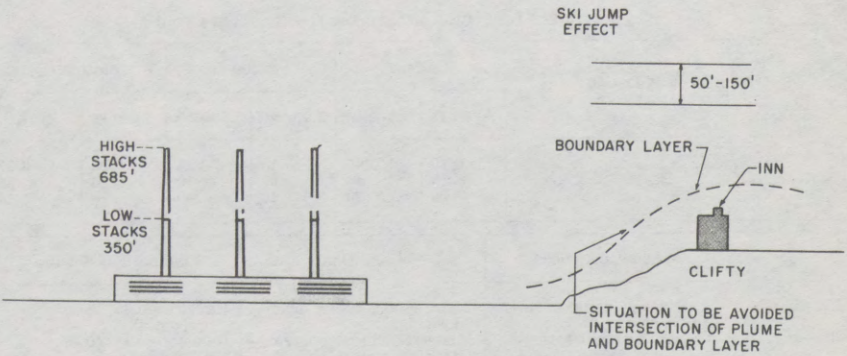


FIGURE NO. 2

Tables 1 and 2 show that recording of any sulfur dioxide was the unusual event and that only the short term peaks approach the design values. These Tables and other data from which they were derived, clearly establish the fact that these tall stacks completely eliminate ground level concentrations during inversions. Only a small proportion of the observed concentrations occurred at night when the inversions are normally present. When concentration did occur at night, it was generally apparent from the winds, temperatures, or observations by the plant personnel, that no inversion was present. Thus, the inversion which is so often described as a "lid" holding down noxious gases, actually becomes a shield preventing the return of stack gases if they are first emitted from a tall stack with a reasonable velocity and at a reasonable temperature.

TABLE 1.—*Clifty Creek plant results: Percent of total hours when 4 or more units were in operation that any SO_2 was detected*

Station gustiness classification [1]	Daylight hours			Night hours		
	A	B	C	A	B	C
B_2	0.6	0.2	0.2			
B_1	1.9	.6	.4	0.3	0.1	0.3
C	.5	.4	.5	.2	.1	.1
Total	3.0	1.2	1.1	.5	.2	.4

[1] Brookhaven gustiness classification.

TABLE 2.—*Typical SO_2 concentrations as measured by Thomas autometers, parts per million*

[A—Valley at 2.5 miles; B—Plateau at 2.25 miles; C—Plateau at 4.9 miles]

Gustiness classification	Station A		Station B		Station C	
	Average	Peak	Average	Peak	Average	Peak
B_2	0.10	0.40	0.10	0.25	0.05	0.20
B_1	.10	.40	.07	.30	.10	.25
C	.05	.20	.10	.40	.10	.40

	When experienced	Condition	Fluctuations of wind
Class B_2	Principally during warm weather.	Light winds, strong solar heating.	Range from 45° to 90° horizontally.
Class B_1	Average normal weather	Moderate winds, moderate heating, sunny to partly cloudy skies.	Range from 15° to 45° horizontally.
Class C	Frequently storm or pre-storm conditions.	Strong winds overcast skies	Not less than 15°.

Figure 3 shows how rapidly pioneering plants of 1952–3 were swallowed in the movement of the electric industry toward larger plants. By 1963 Clifty Creek was seventh in size and Kyger was thirteenth.

The most recent plant to be placed in service on the American Electric Power System is Cardinal, located on the Ohio River about ten miles south of Steubenville, Ohio. Figure 4 shows the similarity of the terrain to that of Clifty Creek Plant. Much the same sequence of wind tunnel studies and diffusion calculations were used, resulting in the selection of 825 foot stacks, with an exist gas velocity of 75 feet per second. Figure 5 shows the surrounding communities and the location of the dustfall and sulfur dioxide sampling stations. While it is too early to know the effect of full load operation of this plant, there is reason to believe that these stacks will follow the successful history of those at Clifty Creek Plant.

At this time high stacks provide the only proven means of disposing of sulfur dioxide. Many suggestions for the substitution of one fuel for another ignore both the economic burden imposed on the user, and the practical engineering

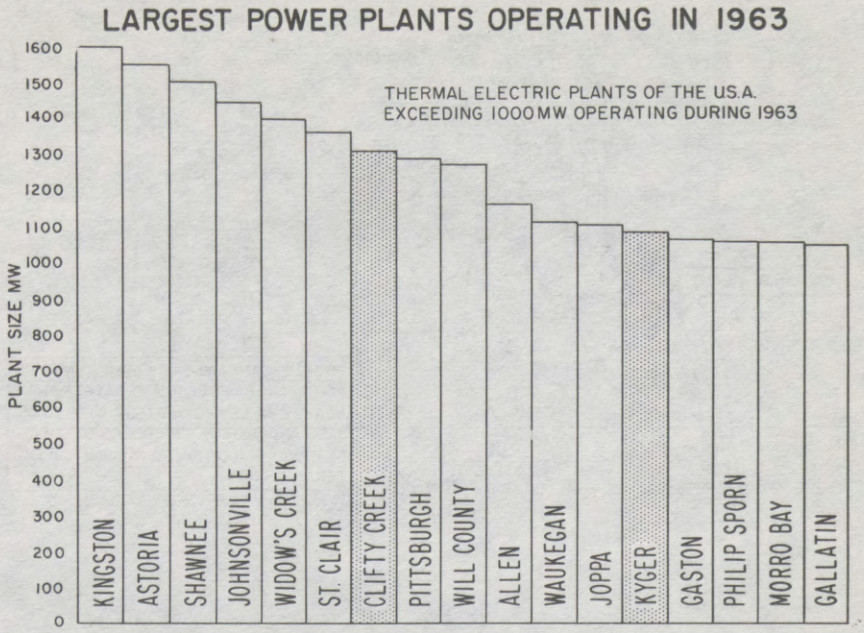


FIGURE No. 3

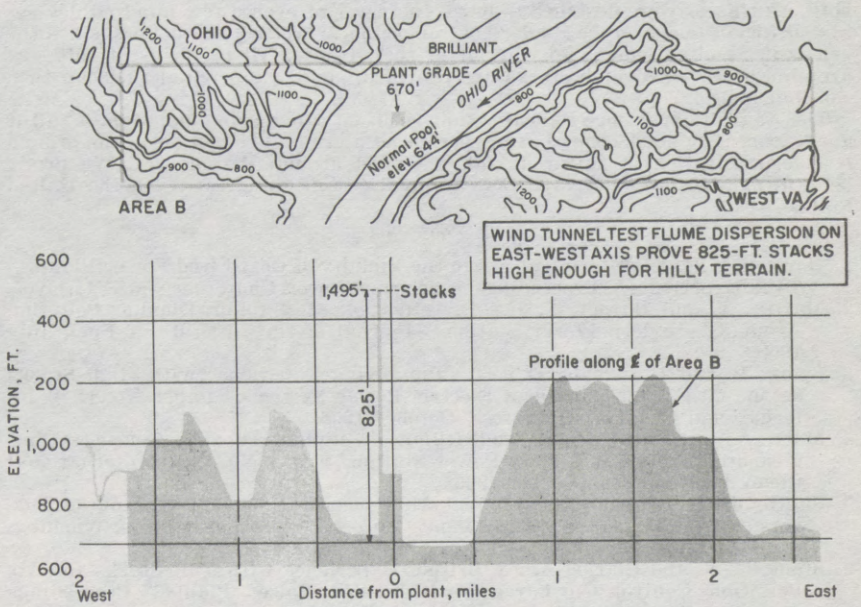


FIGURE No. 4

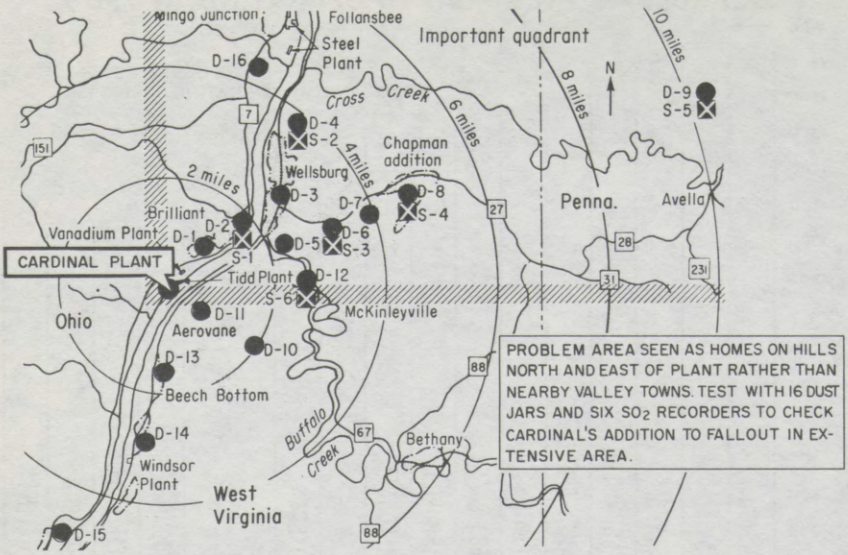


FIGURE NO. 5

problem of burning a very different fuel. For example, must low sulfur coals have much higher ash fusion temperatures than the high sulfur coal, while many wet-bottom furnaces were designed to burn. Increases of even a few hundred degrees in ash fusion temperature render coal unusable in wet bottom boilers, since the ash is not molten enough to run out of the furnace. All problems of this sort are eliminated when high stacks are provided, since the original fuel can then continue in use.

The English experience indicates that even with increasing emission of sulfur gases from high stacks they have experienced a gradual reduction in the ground level concentration of sulfur dioxide recorded around the country. We firmly believe that the use of high stacks can do the same thing for us in the United States.

REFERENCES

1. Gartrell, F. E. "Monitoring of SO_2 in the Vicinity of Coal-Fired Power Plants—TVA Experience." Proceedings American Power Conference XXVII, 1965.
2. Martin, A. and Barber, F. R. "Investigation of Sulphur Dioxide Pollution Around A Modern Power Station." Journal of the Institute of Fuel, July 1966.
3. Sporn, P. and Frankenberg, T. T. "Pioneering Experience with High Stacks on the OVEC and American Electric Power Systems." Paper No. IV/9 International Clean Air Congress, October 1966.
4. Martin, A., Barber, F. R. and Gillam. "Sulphur Dioxide Concentrations Measured Around A Modern Power Station." Paper No. VI/10 International Clean Air Congress, October 1966.
5. Smith, M. E. "Reduction of Ambient Air Concentrations of Pollutants by Dispersion from High Stacks." National Conference on Air Pollution, Washington, D.C. December 1966.
6. Stone, G. N. and Clarke, A. J. "British Experience with Tall Stacks for Air Pollution Control On Large Fossil-Fuelled Power Plants." Proceedings American Power Conference XXIX, April 1967.

Mr. FRANKENBERG. I only would like to point out that the tall stacks work best at the most critical time for the general low-level pollutants. They work for all gaseous pollutants and not just sulfur dioxide. This is important because if we had to come next to a powerplant, and build a gigantic and very expensive SO_2 removal plant, we would still be left with nitrogen oxides in some of the other pollutants and which are alleged to be and may very well be more dangerous than SO_2.

Mr. Avila also referred to alternate schemes.

Senator MUSKIE. Incidentally, I note that you passed over the sentence in which you say:

> It really should not be a matter of great surprise to find that the laws of physics apply equally on both sides of the Atlantic Ocean.

It seems to me that sentence ignores the presence of General de Gaulle. [Laughter.]

Mr. FRANKENBERG. Physical laws by higher authority.

Senator MUSKIE. I am not sure there is higher authority. [Laughter.]

Mr. FRANKENBERG. One of these alternative ideas that has been given wide distribution is the substitution of low sulfur fuels and in some previous testimony the representative of the HEW reportedly stated that one large eastern electric utility could make this transfer at an additional cost of about 6 percent.

It may be that the east coast utilities are in a particularly fortunate position because historically they built their plants to make use of fuels available on the eastern seaboard including residual oil and coal from various sources.

A great many of the plants in the Midwest which I happen to be most familiar with are just in exactly the opposite situation. They are dedicated to burning the one fuel that is at hand. We ran through this for one company that I am familiar with and instead of 6 percent the change in cost was 61 percent.

I think you will find that this is much more typical of the country as a whole than the 6 percent figure that was given to you earlier.

Senator MUSKIE. It is just a matter of a decimal point.

Mr. FRANKENBERG. Sir?

Yes. An order of magnitude, I believe the scientists say. We try to do a little better in engineering. [Laughter.]

There is also an assumption made that when you bring in this low sulfur fuel at whatever cost you are going to be able to burn the material. Well, this is simply not true in some of the cases that are quite commonly used in the electrical utility industry.

I would like to describe the slag tap boiler. This is one in which you cause the flame to impinge on the floor of the furnace and you maintain the ash in the coal in the molten state and you cause it to run out through the slag tap into a tub of agitated water and it breaks up the

slag into these little granules which I would like to suggest you hand to the Senator. In this shape, it can be disposed of very readily.

In fact, the reason we have this in this little tube is that we are able to sell some of it to outside organizations, not by any means all but this can be sluiced away; you can handle it; and, most important of all, it comes out of the furnace.

Senator MUSKIE. What kind of coal is involved in this?

Mr. FRANKENBERG. This would be relatively high sulfur coal, say in the range of 3½ to 4 percent sulfur with very low ash fusion temperatures.

If you substitute low sulfur fuel, it will have the effect that I have shown in the figure 1 in the testimony that the fusion temperature will be raised from 200 to 300 degrees and instead of remaining molten and running out of the furnace, it will pile up on the furnace floor and you will have this sort of glassy, rock-like material sometimes to the depth of 6 feet on the furnace floor.

There is no help to it then but to shut your unit down, get in there with a pavement breaker and mine the stuff out. This is the kind of thing that we know about because occasionally it has happened that high fusion coal has inadvertently got to one of these slag tap furnaces, and this is the sort of thing you just cannot permit to have happen.

So, you are not going to be able to bring this coal from just any old source and put it into these specialized boilers no matter what the sulfur content may be.

We have also, following the Vienna, W. Va., conference in which the conferees decided that all of the boilers in that area should burn coal not exceeding 2 percent sulfur, looked at what it would cost to rebuild these boilers. This is a very difficult and expensive process if you are going to go into it.

We are not even sure that some of it could be successfully rebuilt but the number that we have shown as the cost for this is $114 million for just 17 boilers. I have a letter from one of the boiler manufacturers who points out that in his opinion it would be very close to the original price of the boiler to do this sort of work.

We also have other problems in trying to change to low sulfur fuel. Since these plants in many cases receive the coal from a local mine over a conveyor belt, they had no means for unloading other types of coal.

We find that in order to meet the Vienna, W. Va., conference, we would need to spend about $7.8 million on coal and loading facilities, barges in some cases, additional rail facilities in others. This is an added cost on top of the cost of the low sulfur coal itself which runs about $22 million a year.

We also face a cost for the termination of our long term coal contracts and a complete abandonment of one or two mines which we happen to own outright.

To a greater or lesser extent, this would apply to many other utilities in this same area, and I am not taking my own company as an exceptional case.

Now, when we were sure that sulfur dioxide was as bad as it had been reputed, all of these expenses if they were the only way to go about it might be justified. We not only doubt the SO_2 damage as claimed by the Public Health Service, but we also have a technology which is in hand at the moment and has by measured results over the past 14 years done a good job protecting the ground level concentration around not only our plant but the ones in England, and this is the technology of the high stack.

I have made a comparison, as you will see in the latter part of the testimony.

If we were to do this by high stacks on the remaining plants in this particular company; that is, the older plants do not have high stacks at this moment—if we were to do this, our capital expenditures, including those for better precipitators, would be about $13 million. The carrying charge on this is over a million and a half a year. This is against the cost of changing the low sulfur fuel that was calculated to be about 25 times that amount.

In other words, we have a choice of two things that will do the same job. This is our firm conviction that they will, and we don't see any reason to take the one that is 25 times as expensive as the first one.

Senator MUSKIE. Now, these costs which are summarized on page 20 of your statement relate to what? Your Boston Edison plant?

Mr. FRANKENBERG. No, sir. These relate to a Midwest utility which has the situation of presently designed equipment to burn the local, the contiguous coal reserves of that area.

Senator MUSKIE. I see.

Mr. FRANKENBERG. There are many utilities that are in this same situation.

Senator MUSKIE. So the substitution of fuel would mean abandoning the use of coal that is nearby?

Mr. FRANKENBERG. Yes, sir.

Senator MUSKIE. For coal that is farther removed?

Mr. FRANKENBERG. 100, 200, in some cases 300 miles removed from the plant. Where we know the transportation expense we would now face the cost of——

Senator MUSKIE. So that these costs have that situation.

Mr. FRANKENBERG. Yes, sir; and the cost of rebuilding the boilers to burn the low-sulfur coal after you got ahold of them.

The other things that are often mentioned are to substitute gas firing for coal. We find that this is about 30 times as expensive as the conversion to high stacks. The same thing applies for oil firing. I would say about 30 times there.

The electric utility industry is justly proud of its history of being able to lower rates. It will be a sad day if the time should come that this historical trend has to be reversed. It would be a thousand times worse to have this reversal occur as a result of well-intentioned but unnecessary rules of the U.S. Public Health Service.

First, as I have stated, there is considerable evidence abroad that sulfur dioxide is not nearly connected with health as they have claimed; and, second, even if it were, we have in the technology of the high stack an excellent means to prevent it reaching ground level where it can be in contact with people, animals, and vegetation. We believe that the ground level concentration is the point at which it becomes a legitimate concern of those people charged with protecting the health and welfare of the citizens.

Thank you.

Senator MUSKIE. With respect to considerations of cost and conversion, I wonder if you could submit to us the analysis which leads to your conclusion about low sulfur fuel substitution which you say costs 25 times as much as the high stacks with precipitators and gas fuel substitution which you say costs 30 times as much as high stacks with precipitators and also the oil firing estimate.

If there are such high figures, I would like to see a breakdown or analysis to understand them fully.

Mr. FRANKENBERG. Yes, sir. These can be made available. We will have them for you in a very reasonable time.

Senator MUSKIE. All right.

Now, Mr. Smith.

STATEMENT OF MAYNARD E. SMITH, LEADER OF THE METEOROLOGY GROUP, BROOKHAVEN NATIONAL LABORATORY

Mr. SMITH. I am Maynard E. Smith.

Most of my research involves atmospheric turbulance and dispersion and that sort of thing. Among other things, at the present time I am chairman of the ASME task group whose chief function is to summarize our knowledge of these processes and to suggest facilities and procedures for achieving the most effective dilution of pollutants.

Last December, I was invited to give a paper at the National Conference on Air Pollution which is mentioned in the summary of my talk, and I think that this covers most of the points more fully than I would have time to do this morning. I would like to have it included as a part of the record.

Senator MUSKIE. I will order it placed in the record at this point.

(The paper referred to follows:)

REDUCTION OF AMBIENT AIR CONCENTRATIONS OF POLLUTANTS BY DISPERSION FROM HIGH STACKS

Heat and Power Generation - Panel B

National Conference on Air Pollution

Maynard E. Smith

Meteorologist

Brookhaven National Laboratory
Upton, Long Island, New York

In the past fifteen years the high* stack has become almost symbolic of good industrial air pollution practice, and its use as an effective and economical device for reducing ground-level air pollution has become widespread. Although this session deals specifically with heat and power, the discussion is applicable to any similar operation. My principal purpose is to specify what a stack can and cannot do, and to emphasize several important, unresolved questions upon which the ultimate value of the stack depends. The data that have led to my conclusions have come from too many sources to permit complete references, but bits and pieces have been extracted from a surprising variety of research projects. These projects have usually been conducted exclusively within a single administrative domain, and it has occurred to me many times during my preparation that we are in need of "integration" in this field also. There is much important, expensive work to be done, and I am firmly convinced that we will make more rapid progress and achieve better understanding by means of genuinely cooperative projects, with staffs and facilities dictated by technical requirements rather than organization boundaries.

- - - -

*Any definition of a 'high' stack is arbitrary, but in this paper it is one reaching 500 ft or more above ground.

I should also admit before you remind me that much of my material is not new. The author of a "state of the art" paper always feels obliged to dig through the dusty files to make certain that he does not ignore significant contributions, and incidentally to be sure that he does not display any lack of erudition himself. In my case, the digging process has been humbling as well as helpful since it has reminded me once again that several early workers in this field understood, and eloquently expressed, most of the points I hope to make clear.

As far as I can determine, the first genuine devotees of the high stack were not in the heat and power field. Long before most of us had begun to think of a stack as something more than an aid to combustion draft, the American Smelting and Refining Co. was creating traumatic shock by using 400 - 600 ft chimneys to reduce sulphur dioxide pollution from smelting operations. I remember vividly some disparaging remarks that accompanied their pioneering papers, and this accounts in part for my satisfaction in being able to recommend to you a re-reading of the 1945 paper on high stacks by George Hill, Moyer Thomas, and John Abersold. There are earlier works on the subject to be sure, but this paper is unique in firmly establishing the value of the tall stack by means of thorough field investigations. It is also noteworthy for its recognition of the importance of maintaining buoyancy in large-volume plumes (some of us have had to relearn this lesson), and for clearly stressing the difference between average and peak concentrations, especially in light winds.

One cannot conduct any review without including Hewson's classic study of the plumes from the Trail smelters (1945). His description of the Columbia River valley circulation and its effect on the ground-level SO_2 concentrations is still pertinent, especially since little work of equivalent quality has been performed in valleys since that time. Hewson was also a pioneer in drawing our attention to the "fumigation" condition, which was a significant factor in the Trail problem and remains an important problem today.

The electric power industry seems first to have become enchanted with higher stacks for the solution to the aerodynamic downwash problem, which was very common with the typical "75-ft building, 100-ft stack" power station of the 1920-1950 era. In fact, the University of Michigan and New York University wind tunnels were used so successfully to determine the stack increments required to alleviate these high-wind problems that we meteorologists had some difficulty in convincing power company executives that even taller stacks might provide additional benefits.

I had the pleasure of being associated with one of the first studies of a major fossil-fuel plant completed prior to final design and construction. This study of the Clifty Creek plant in the Ohio Valley included both wind-tunnel tests and a theoretical evaluation of ground-level SO_2 concentrations and dustfall. The program also provided for another unusual feature - continuous monitoring of the field SO_2 concentrations and dustfall after the plant was completed. It is gratifying today to direct your attention to the paper that Frankenberg and Sporn recently presented in London (1966), as proof that the 680-ft stacks have performed as anticipated, except that the "inversion break-up fumigation" concentrations predicted in the original study have not been observed.

Today, almost every major power plant designed for fossil fuel includes a stack chosen to keep ground-level pollution within acceptable limits. Formal study of individual plants varies according to the complexity of the area, the size of the plant and the sophistication of the organization, but air pollution abatement function of the stack is as much a part of the design consideration as boiler and turbine details.

The trend in the industry is clear enough - fossil fuel plants are constantly increasing in individual size as power requirements and economics dictate. Stack heights are increasing also, in response to the trend in plant size and in recognition of the need for maintaining lower ambient air concentrations. The new Bull Run plant of TVA and the Cardinal plant of the American Electric Power system will have stacks reaching the 800 ft level, and 1000 ft stacks will soon be seen in western Pennsylvania. If one needs further proof, Olmstead (1966) tells us that the average height of stacks to be completed in 1969 for coal-burning power plants will be 609 ft as compared to 243 ft in 1960. Faced with such an obvious trend, we should indeed be asking ourselves what stacks can and cannot do. We have acceptable answers to many specific questions, but there are important aspects of the behavior of stack gases that remain poorly defined.

There are several benefits to be obtained from the use of a tall stack (or any stack for that matter) about which no one will argue seriously. Experts are not in perfect accord about the exact degree of benefit or the manner in which it may be achieved, but there can be no quarrel over the reality of the effects.

Under any meteorological conditions, a tall stack located in open, uncomplicated terrain will produce a dramatic reduction in the local ground-level concentrations of gases or small particulates compared to the same emission released at low levels. The degree of reduction and

the size of the area over which it occurs are dependent upon the stack height, the distance from the source and the meteorological conditions, but there is always a region near the stack where the improvement is impressive. This reduction is accomplished simply by giving natural atmospheric turbulence an opportunity to dilute the pollutant before it reaches ground-level receptors. In Table I, for example, the maximum concentration at ground-level under typical daytime conditions is reduced by a factor of 100 by a ten-fold increase in source height. Significant though much smaller reductions occur as far as 10 km from the source.

It is also important to realize that a stack located in open terrain converts the least favorable meteorological condition into the most favorable. Within a well-developed temperature inversion the mixing process is extremely slow and ineffective, particularly in the vertical. For all practical purposes, a plume emitted at any reasonable height above ground in an inversion remains aloft indefinitely, producing no ground-level concentrations, as indicated in the lower section of Table I. A photograph of such an inversion plume (Fig. 1) shows that concentration within the plume changes little with distance, but it remains aloft.

A stack can be a most effective tool for removing a plume from a specialized local wind circulation that tends to bring pollutants to ground-level in higher than normal concentrations. Even an elevated source in the lee of a large building or terrain obstacle, as in Fig. 2, may produce undesirable effects nearby, whereas an isolated stack would not. This is the classic aerodynamic downwash problem mentioned earlier, and the solution is usually an increase in stack height sufficient to remove the plume from the offending circulation.

While the typical downwash problem is easily solved by a wind tunnel study, there are other types of local circulations which are difficult to model. It is clear, for example, that a significant portion of the difficulty experienced with the Trail smelters resulted for specialized circulation in the Columbia River Valley, as indicated in Fig. 3. Patterns of this type are not so easily recognized, nor can they be represented in tunnels since they are primarily thermally-generated phenomena associated with light winds. The problems they might create are often solved automatically, however, since the requirements for a high stack based upon conventional analysis will frequently remove the effluent from a low-level system of this type.

This list of positive accomplishments of the tall stack is short, but it is unquestionably impressive. In the local area near a large pollution source, the only possible alternative would be reduction of the emission by the huge percentages suggested by Table I, and it would seem that our technology is not quite equal to the task as yet.

TABLE 1.—*Hypothetical ground-level concentrations from various effective stack heights*

	Distance of Max (km)	Concentrations Directly Downwind (ppm)				
		Maximum	1km	5km	10km	50km
Typical Daytime Conditions						
Plume Height - 1000m	7.6	.03	0	.03	.03	.004
500m	3.4	.14	< .01	.12	.05	.004
100m	0.6	3.36	2.2	.19	.06	.004
Ground	(at source)	-	3.1	.19	.06	.004
Surface Inversion Conditions						
Plume Height - 1000m	(Beyond 100 km)	-	0	0	0	0
500m		-	0	0	0	0
100m		-	0	0	0	.03
Ground	at source	-	1,590	161	60	6.0

Having extolled the virtues of the tall stack, we must also keep in mind the things it cannot do. Influenced by knowledge of its real benefits and perhaps sometimes by wishful thinking, we often find the tall stack receiving credit for purely fictitious accomplishments. I remember an early press story about Brookhaven's Graphite Research Reactor as a classic example - it stated boldly that the reactor would operate only when the radioactive Argon gas from the stack dispersed upward and would not come to the ground. I remember equally well four long-faced meteorologists wondering how they might answer queries based on that misconception.

The fact of the matter is, of course, that stacks possess no magic power to eliminate a pollutant. They do not reduce by one gram the total amount of pollutant released to the atmosphere. They distribute it in a different way than would be true of a low-level source, but a receptor at a great distance from a stack will receive substantially the same concentrations no matter what the source height. Both Table I which illustrates the hypothetical effect of varying source height and Table II which depicts the performance of an actual power plant stack show this effect clearly. This failure to effect a widespread reduction is the essential reason for continued emphasis on restricting the total amount of emissions by those concerned with large-scale pollution problems. It is a valid reason as long as the pollutant does not change to a less objectionable form while airborne, but this possibility will be discussed more fully in a later section.

There is one popular misconception closely allied to the local vs regional viewpoint that should be firmly quashed, and that is the idea that a stack merely transfers a given pollution problem from one area to another. This idea probably originated with the change in the position of the maximum concentration as the stack height increases. What is often ignored is the fact that the magnitude of the ground-level concentrations decreases everywhere as the stack height increases, as is clearly shown in Table II. True, at 20 km one may not be able to measure the decrease in concentration associated with a small increase in stack height, but the tendency is always to reduce, not to increase the concentration. Another possible source of this misconception is that a change in stack height may involve a change in wind direction so that the pollutant reaches a different area as the stack height changes (Fig. 4). This still does not imply that increasing stack height means higher levels of concentration.

We have a common view in this country that if one unit is good, two will be twice as good, ad infinitum. Automobile horsepower and cigarette length are sufficient examples. Looking at any of the equations developed to represent the maximum concentrations from a stack, we find a $1/h^2$ term,

TABLE 2.—*Concentrations at the maximum, 10 KM and 20 KM from a 600 MW source in typical daytime conditions*

Actual Stack Height		Distance of Max	Concentrations (ppm)		
(ft)	(m)	(km)	Max	10 km	20 km
750	230	4.0	.10	.044	.015
600	185	3.6	.13	.045	.015
500	155	3.2	.15	.046	.015
400	120	3.0	.18	.046	.015
350	105	2.9	.19	.047	.015
300	90	2.8	.20	.047	.015
250	75	2.6	.21	.048	.015
200	60	2.5	.22	.048	.015

(h is the stack height) which implies that we are even better off with stacks, since doubling the height of a stack should reduce the concentration by a factor of four. As with dry martinis, the approach has certain flaws, particularly when applied to large power plants whose stack emission includes a very substantial volume of hot gases. With such plants, the true source height is achieved by an addition of the actual stack height and a combined momentum-buoyancy rise of the gas, and the latter is an appreciable quantity. From a 600 MW plant with a typical gas emission, for example, the plume rise ranges from a few hundred feet in strong winds to thousands of feet in light winds. Thus a substantial addition to stack height does not produce quite the effect that a cursory examination of the equations might suggest, since the plume rise is a much larger number than the stack height. Furthermore, as larger plants are constructed with commensurately higher chimneys, it appears that the limiting meteorological condition (i.e. that producing the highest ground-level concentrations) tends to become associated with light winds and strong vertical mixing. Any theoretical evaluation which includes the buoyant plume rise will predict this result, and Gartrell (1966) has found it to be true in practice. This light-wind condition is precisely the case in which the buoyant plume rise is greatest and the effect of an addition to the physical stack least.

There must therefore be a practical upper limit to the maximum power plant stack height and size when one considers these diminishing returns together with questions of cost, construction difficulty and aircraft hazards. What this size limit may be depends on the amount of pollutant in the emission, the frequency of the unfavorable meteorological conditions and the definition of acceptable concentration levels. It also depends on the answers to a number of questions that have not yet been answered to everyone's satisfaction, and it seems that a review of these questions may be the most valuable contribution that I can make at this conference.

In view of the two preceeding paragraphs, the most obvious problem to single out is the prediction of plume rise. Over the years, we have been deluged with theoretical and empirical formulas predicting the rise of a plume having both momentum and buoyancy, but even today we have little good field data to help us choose among them. I know from personal experience how difficult it is to assess the rise of a cloud or plume which is simultaneously being dispersed by natural turbulence, but we must achieve more reliable prediction of this phenomena. At the most recent ASME meeting in New York, The Task Group charged with preparing the Guide for Atmospheric Dispersion reported upon still another formula, and while we believe it to be the best available, we recognize that it is not in full accord with all data or viewpoints. The principal bone of contention is whether the heat release rate should be raised to the 1/4 or the 1/2 power, a difference which implies variations of hundreds of feet in effective stack height for the large power plant plume.

Extension of any formula to multiple stacks is even more speculative. Fortunately, we do have some helpful data from TVA (Gartrell, 1966) but much of it is in terms of ground-level concentrations rather than plume behavior itself. Perhaps we could avoid this research problem entirely by using the compartmented single stack now favored in Britain, but we still have many new multiple stack plants under design.

I feel sure that my colleagues agree that much remains to be learned about plume rise, but wonder if I am not emphasizing unnecessarily a problem which we can at least treat fairly well. There is reason for the emphasis, however, because estimates of plume ascent are vital to a crucial question, that of the fumigation concentrations from power plant plumes. If one were asked to choose two words from an air pollution glossary guaranteed to strike terror in the hearts of the populace, he would have a hard time selecting more effective ones than "fumigation" and "inversion". The wide publicity given inversions in relation to the specialized problems of Los Angeles, and the lethal connotation of fumigation have given the two words stature. It is little wonder, therefore, that the pamphlet published by Pooler (1965) has caused widespread concern, since he described a calculation method for an "inversion break-up fumigation" which predicts very high ground-level concentrations in the morning hours immediately following the destruction of a surface temperature inversion. All such calculations (and there have been many) assume that a narrow pencil-like plume such as that shown in Fig. 1 is mixed downward into the air below, but not upward because of an inversion remaining aloft. The details vary in how thick a layer may be involved, how much of the plume may penetrate into the inversion and how wide a swath may be affected, but the picture to keep in mind is one of a large amount of SO_2 confined to a small volume close to the earth's surface.

The essential question is not whether such a process can ever occur. Certainly, the Trail experience was related to phenomena of this type, and measurements of cool oil-fog plumes at Brookhaven Laboratory have shown that it can (Lowry, 1950). Rather, the question is whether such phenomena are found with the typical large power plant plumes, and if so, under what conditions and how often.

There are several reasons for caution about accepting the validity of such calculations for large emissions. In the first place we know that these plumes may reach altitudes of 1000-2000 ft above the surface, and while the flow at these heights is still technically a part of the planetary boundary layer, it is often in a transition zone between the region close to the earth's surface and the free air above. We have not studied the turbulence in the higher layers in any detail as yet, and extrapolation of our knowledge of the lowest 500 ft to much higher elevations is not without its dangers.

It is also true that the typical radiation or surface inversion usually appears as a layer reaching only 500 to 1000 ft above the surface, but the large power plant plume is likely to penetrate a relatively weak inversion layer (if any) remaining above it. Whenever this happens, and it probably is a common occurrence, the plume approaches the ideal of dispersing upward but not downward.

Furthermore, most radiation inversions probably do not break down in quite the orderly progressive manner initially supposed by many of us, wherein an unstable layer gradually builds up from the surface while a portion of the inversion remains above it. On the contrary, it is highly likely that upward dispersion begins at about the same time as downward dispersion for plumes that are already high in the air.

The most compelling reason for caution is that experience with several large power plants has failed to show fumigation concentrations of the order predicted. Initial calculations made for the Clifty Creek and Kyger Creek plants included inversion break-up estimates of my own devising, which like a contemporary development by Hewson (1955) and Pooler's recent system predicted concentrations of 2-5 ppm. Frankenberg and Sporn (1966) report that four years of continuous monitoring failed to verify the prediction at any time at either plant. Martin and Barber (1966) in an intensive study of a modern 1000 MW plant in England also state that "No unusual station effects were observed at the break-up of inversions, with the present recorder array." Similarly, Gartrell reports a peak observed value of only 0.6 ppm for a 1250 MW plant equipped with 500 ft stacks over a 19-month period. With the 3% sulphur coal burned, Pooler's inversion fumigation calculation predicts 3.0 ppm and his "light wind fumigation" at least 2.0 ppm for Gartrell's example.

It can be argued that fumigations occur infrequently and that one must sample in just the right place at just the right time to observe them, but if years of continuous sampling at a given site do not reveal such high concentrations, one wonders whether the calculation is valid. The essential questions are (1) whether these large plumes often penetrate relatively low or weak inversion lids, and (2) when they are trapped below such lids what precisely is the nature of the dispersion.

Another important area of uncertainty that probably will be with us for a much longer time involves atmospheric flow patterns associated with terrain features that are of very large scale. I have already indicated that the Trail experience seems to have been one of those specialized cases wherein the highly concentrated plume was trapped in a major valley circulation with unfortunate results. There are other studies as well which indicate that we may be in for some rude surprises if plants are built in very rugged terrain. Smith (1965), for example, has reported that under certain stability conditions tracers released high above and upwind of a

ridge top have appeared far below along the lee slope, although they certainly would not be expected there on the basis of standard calculations. Fig. 5 shows the wave type of flow pattern that Smith found. Sea and lake breeze circulations are in this same large-scale category, and it would not be surprising to find significant departures from standard diffusion calculations associated with them, especially as plants become larger. We cannot yet generalize reliably, but we must be careful to investigate actual flow patterns before construction in complex areas.

There is one additional problem about which very little has been said to date, and that concerns the atmospheric half-life of contaminants such as SO_2. Obviously most pollutants do not remain in the atmosphere indefinitely - we would all have ceased to exist centuries ago if this were true. A variety of chemical and physical processes alter the pollutants and eventually return them to the earth's surface. These processes have typical time scales that are fairly short, generally not more than weeks and sometimes as short as a few hours. If atmospheric processes reducing the objectionable character of a pollutant produce half-lives of 12 hours or less, we must revise our earlier statement that stacks fail to reduce total pollution over a large area. Because tall stacks typically cause pollution to remain aloft for long periods, even for an entire night during an inversion condition, it is quite possible that they also have the effect of reducing total amounts.

To summarize, the power industry has found the tall stack to be an excellent means of reducing ground-level pollution, producing a greater effect per dollar spent than almost anything else. While the stack may not eliminate the overall burden of pollution borne by the atmosphere, it will remain an important feature of our anti-pollution efforts until much more practical and reasonable means of reducing emissions are at hand.

Perhaps the most critical problem today is to determine the limiting size of a single fossil-fuel plant, and among other factors this depends upon an accurate assessment of stack performance. Differences in dispersion calculations alone cause such estimates to vary by almost an order of magnitude. Resolution of these differences depends upon finding the answers to questions such as those I have raised in this paper, and it is clear that we are not going to obtain the answers through haphazard research oriented toward minimum cost and organizational secrecy rather than accurate, pertinent data.

The Task Group preparing the new ASME Dispersion Guide was initially naive enough to believe that ASME prestige and influence might flush enough good field data from dusty files to permit reasonable verification

77-515 O-67-pt. 4—23

of the evaluation procedures that are to be recommended. With a few signal exceptions, this part of the work has been a dismal failure, and we cannot offer much more than one can find in the existing open literature.

We urgently need answers to these questions and it is time to undertake imaginative projects that will provide them. The recent proposal for intensive study of the 1000 ft stack plumes in western Pennsylvania is cast in the proper mold. Originating within the Public Health Service, it cuts across organizational boundaries to include government, industrial, university and private personnel and facilities in a joint effort to obtain the desired data. As emphasized in announcements for this conference, it certainly "will take the combimed efforts of industry, government, science and the community to conquer the problem."

References

Frankenberg, T. T. and Sporn, P., 1966: Pioneering Experience with High Stacks on the Ohio Valley Electricity Corp. and the American Electric Power System. Int. Clean Air Conf., London, Oct. 1966.

Gartrell, F. E., 1966: Control of Air Pollution from Large Thermal Power Stations, Revue Mensuelle 1966 de la Societe Royale Belge des Ingenieurs et des Industriels Bruxelles. p. 8.

Hewson, E. W., 1945: The Meteorological Control of Atmospheric Pollution by Heavy Industry, Quart. Jour. Royal Met. Soc., Vol. 71, pp. 274-277.

Hewson, E. W., 1955: Stack Heights Required to Minimize Ground Concentrations, Trans. ASME, Oct. 1955, p. 1165.

Hill, G. R., Thomas, M. D. and Abersold, J. N., 1945: High Stacks Overcome Concentrations of Gases. Mining Congress Journal, April 1945, pp. 21-34.

Lowry, P. H., 1951: Microclimate Factors in Smoke Pollution from Tall Stacks, Meteor. Mon., V1, No. 4, pp. 24-29.

Martin, A. and Barber, F. R., 1966: Investigations of Sulphur Dioxide Pollution around a Modern Power Station, Journal of the Institute of Fuel, July 1966, V39, No. 306, pp. 294.

Olmstead, L. M., 1966: 9th Steam Station Design Survey, Electrical World, Oct. 1966, p. 101.

Pooler, F., 1965: Potential Dispersion of Plumes from Large Power Plants, U. S. P. H. S. Publication #999-AP-16.

Smith, T. B., 1965: Diffusion Study in Complex Mountainous Terrain, Meteorology Research, Inc. report to Dugway Proving Ground, U. S. Army Chemical Corps AD484087, pp. 106-110.

List of Figures

1. Inversion Smoke Trail

Photograph of oil fog trail shortly after sunrise during a deep, temperature inversion extending well above the smoke trail. The source was at 108 m and 3 miles of trail are visible.

2. Aerodynamic Downwash

Standing eddies in the wind flow behind the building bring pollutants from a low stack quickly to the ground.

3. Valley Circulation

Local circulations caused by unequal heating and cooling within valleys may create unusual dispersion patterns.

4. Change in Wind Direction with Height

A change in stack height may change the location of pollution. The three smoke trails shown were emitted during a temperature inversion at 50, 150 and 350 ft above ground.

5. Large Scale Wave Pattern

Flow patterns associated with major terrain features may cause pollutants to reach the ground in unexpected areas.

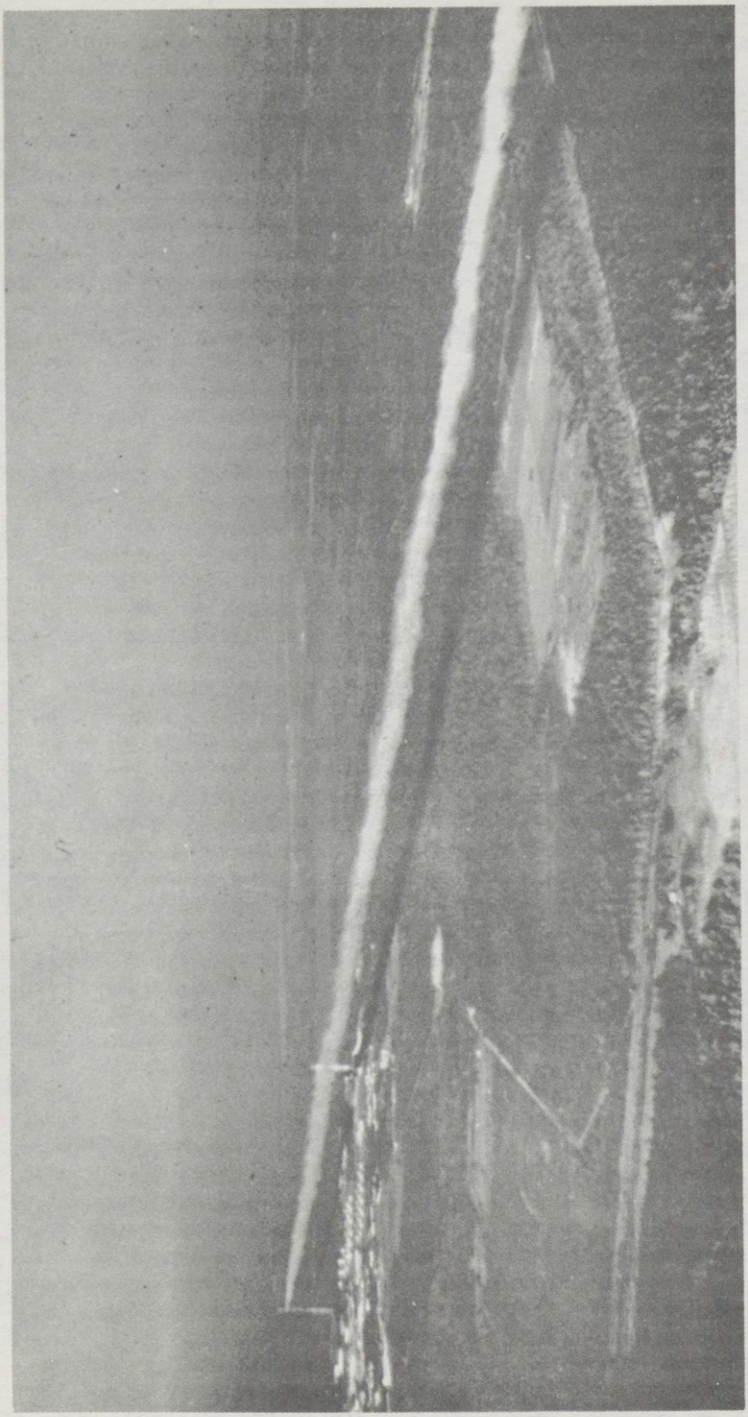


FIGURE 1

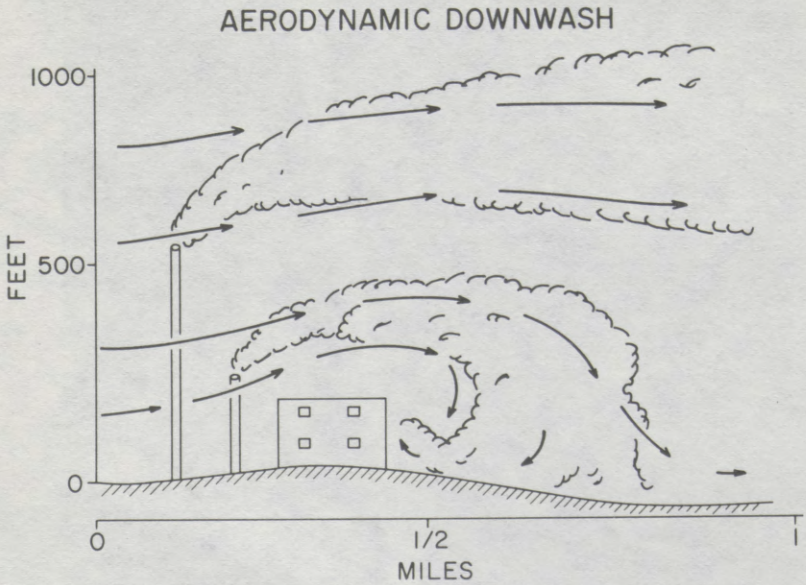


FIGURE 2

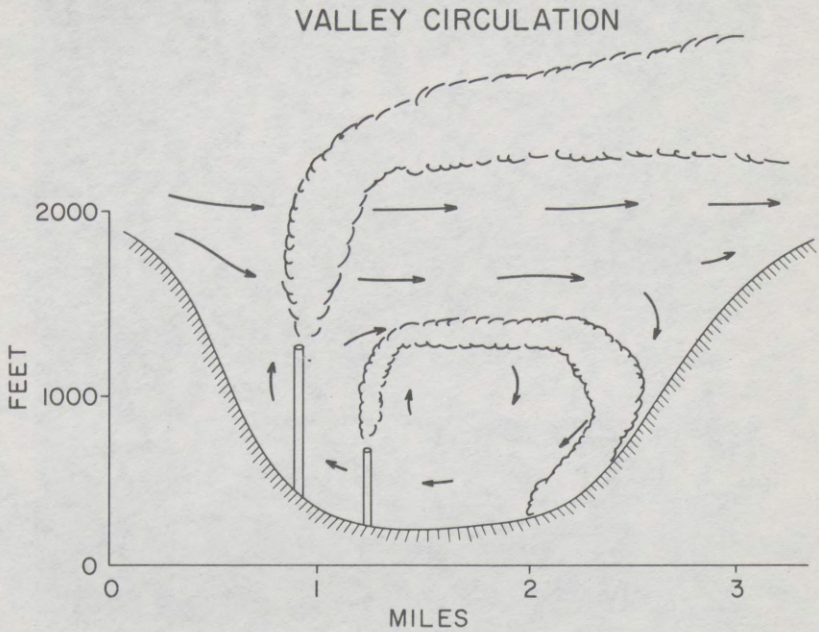


FIGURE 3

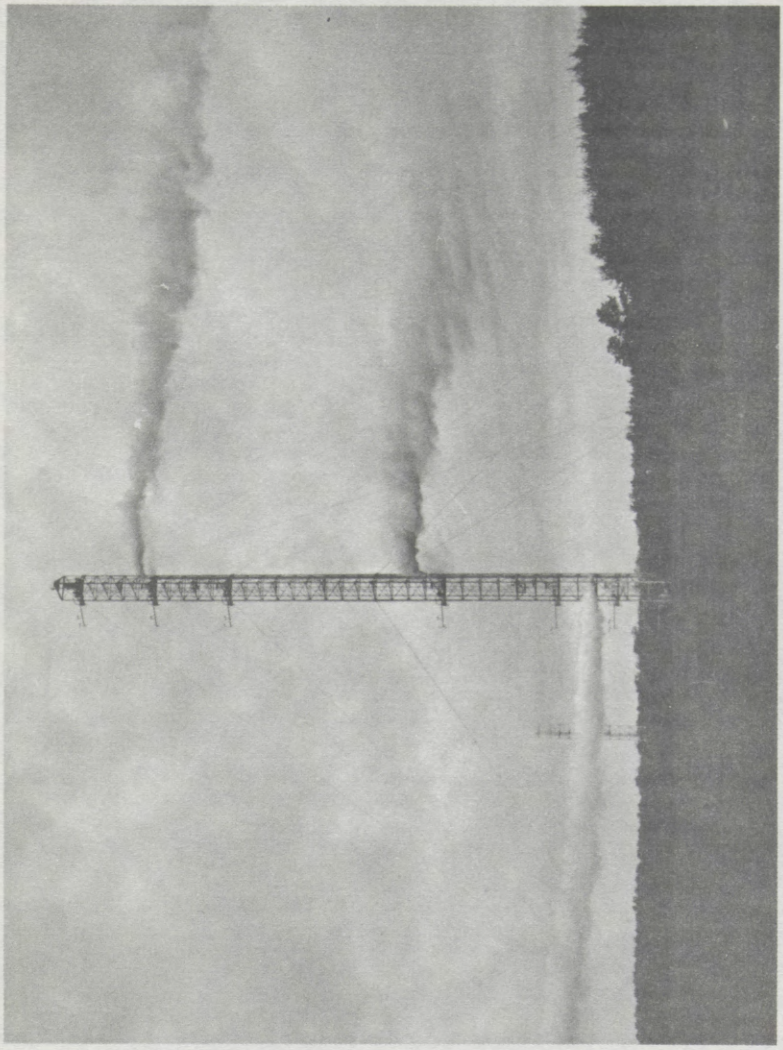


FIGURE 4

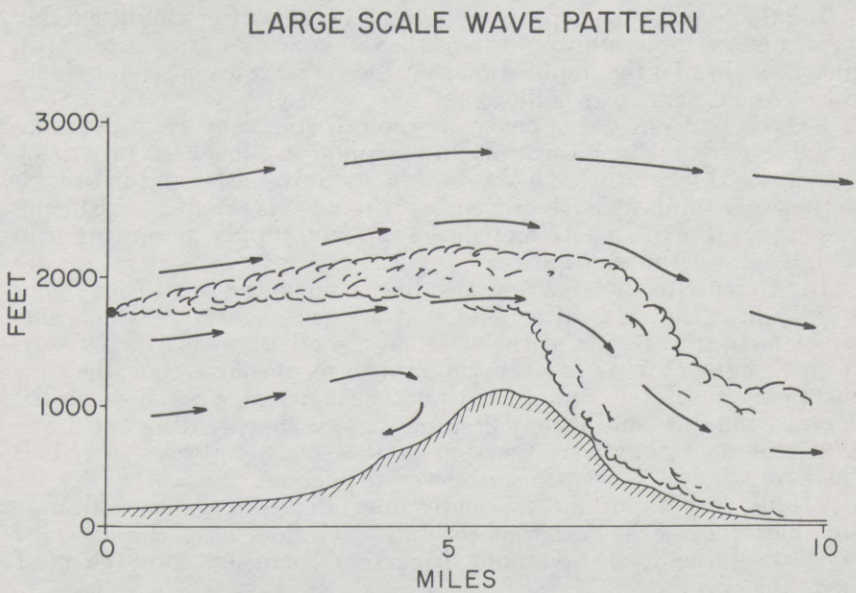


FIGURE 5

Mr. SMITH. Now, I think this morning as we have heard many times before there is an implicit equation of the size of emissions with the size of effects.

One of the points that I would like to make is that the tall stack, I think, is extremely well proven, an extremely well-proven device for reducing the effect; namely, the ground level concentration and inhalation of pollutants, by means simply of putting the material at a sufficiently high point in the atmosphere to give it time to accomplish adequate dispersion before it reaches the ground.

In other words, the type of thing that I see so often published and presented would be a breakdown of the total emissions in a given area, and I would find the implication that the very large emission by definition means very large pollution.

I think that our development of the tall stack and its proof as a suitable system, which certainly in my judgment has been proven by our national laboratories, TVA, and many universities and industrial activities, I think we have proven that the stack is capable of reducing the importance of an extremely large emission supply by putting it in a high point in the atmosphere.

In reference to this, I would also like to make the point that I constantly hear that it is often said that a stack merely transfers your problem from this side of the street to the other, with which I seriously disagree; it is a misconception. It is true, of course, that when one introduces a tall stack and usually puts the material in a somewhat different wind flow, and it may go in an indeed sharply different direction sometimes, however, function of the stack is always to reduce the ground-level concentration, never to increase it.

I think very important, especially in reference to earlier testimony this morning, is the fact that the tall stack does have the effect of converting the least favorable dispersion condition into the most favorable.

In other words, the temperature inversion which is unquestionably a very serious proposition with a series of very low level sources becomes the best condition that we actually see when utilized in reference to a tall stack.

The buoyancy of the gases, in addition to the original high point of release, virtually always keeps the concentration well above the ground with the result that there is very little concentration at ground level under such conditions.

Furthermore, I believe there is a rapidly growing body of evidence not of the quality I think that you would like to have at this session, but very distinctly growing body of evidence that indicates that the primary difficulty in these episodic problems which I believe are the ones that concern us most are the host of small low services as opposed to a modest number of individual high sources.

Mr. Frankenberg has already mentioned my point 5 on the tall stacks simultaneously. I don't think it is attributable. I think it is important but I need not stress it.

Now, as you are well aware, I am sure, there are questions among us regarding the effectiveness of stacks. For example, Dr. Ludwig mentioned this morning the light wind conditions that they were concerned about. If I interpret the calculations he was talking about cor-

rectly, at least it is one that appears in the Public Health bulletin, I would judge that this calculation eliminates the stack from consideration; it simply says the stack is of no importance in this case.

Now, this type of debate continues. I feel that there is no evidence to support this particular calculation but there again we are in a position where it is difficult to prove it one way or the other.

I think the most telling point that I can make to you is that I am convinced in working with industrial people for many years that in the power industry, for example, even if we reduced by some great good fortune the sulfur content of all fuel by 0.2 percent of its present value tomorrow, and even on the basis of that our regulatory standards were such that we would say you don't really require a stack, I am virtually positive that everyone of them would continue to use stacks.

In other words, the device is so well proven they would still need the stack installation for a twofold purpose.

So, having worked with air pollution problems for 20 years, it is easy for me to appreciate the appeal of a single across the board, as Senator Spong pointed out. I do feel, however, in terms of both justice and effectiveness, we need a set of standards that will take into account local and environmental conditions and indeed pay individual attention to many of these very large sources because my own experience indicates that they are individual problems in each case, that you can't set a single number which will accomplish your total purpose in this relation.

So, my conclusion is that any legislation on air pollution should recognize the utility of high stacks and then include topography, meterological conditions and the source conditions of the region. Local or regional regulations which take into account special problems are clearly preferable in my mind to uniform national standards.

Senator MUSKIE. Your complete statement will appear at this point.

(The prepared statement of Mr. Smith is as follows:)

PREPARED STATEMENT OF MAYNARD E. SMITH

I. INTRODUCTION

I am Maynard E. Smith, Leader of the Meteorology Group at Brookhaven National Laboratory, and consultant to several industrial organizations on air pollution problems. Pertinent biographical details and a list of major publications are appended. Most of my research involves atmospheric turbulence and dispersion. The chief function of an ASME Task Group of which I am Chairman is to summarize our knowledge of these processes and to suggest facilities and procedures for achieving the most effective dilution of pollutants.

II. NATIONAL CONFERENCE PAPER PERTINENT

In December, 1966, I presented a paper at the National Conference on Air Pollution entitled "Reduction of Ambient Air Concentrations of Pollutants by Dispersion from High Stacks". In this paper, I attempted to summarize the current thinking of leading members of my profession concerning the value of high stacks. I consider this paper germane to these proceedings, and I respectfully request that it be entered as part of my presentation to the Committee.

III. TALL STACKS CAN CREATE ENORMOUS REDUCTIONS IN MAXIMUM GROUND-LEVEL CONCENTRATIONS

There is no question that a tall stack is a most effective means of reducing the ground-level concentrations. Simply by releasing a pollutant at a point high

enough to give the atmosphere time to accomplish dispersion, we can achieve reductions as great as one to ten thousand in the peak concentrations in the air we actually breathe. That this reduction is a reliable process has been repeatedly verified both in this country and abroad. Our National Laboratories, the Tennessee Valley Authority, many universities and industrial organizations have conducted experiments and studies establishing the major features of stack gas behavior and no significant differences have been found between our results and those in Europe.

Despite this evidence, it is often said that a stack merely transfers the pollution problem from one place to another. This misconception is probably associated with the change in location of pollution concentrations that often accompanies the use of a taller stack, but it completely ignores the important reduction in maximum concentrations that results from the increase in stack height.

IV. THE TALL STACK CONVERTS THE LEAST FAVORABLE DISPERSION CONDITION TO THE MOST FAVORABLE

We all recognize that the dispersive capacity of the atmosphere varies markedly from time to time. One who has observed the contrast between a heavy, smog pall over a city in poor dispersion conditions, and the sharp skyline of a gusty, winter day needs no formal scientific proof. Not so readily appreciated is the tendency for the tall stack to be most helpful in the poorest dispersion conditions. During a typical temperature inversion, when pollutants released at low-level are trapped close to the earth's surface, the emission from a tall stack remains aloft and does not contribute appreciably to the ground-level pollution. The high point of release together with the additional rise of the stack plume resulting from buoyancy, frequently causes the plume to break through the inversion and thereafter to remain above it.

Thus, I feel that there is a constantly growing body of evidence indicating that we must turn our attention primarily to the host of small, low-level sources if we are to eliminate the air pollution episodes which concern us most.

V. TALL STACKS ACT ON ALL POLLUTANTS SIMULTANEOUSLY

Most emission control techniques act selectively on a single chemical or a limited group of pollutants. The removal of sulphur from coal or oil, for example, may have no effect at all on nitrogen oxides or fly-ash particles. The use of a tall stack, however, automatically reduces the ground-level concentration of every pollutant in the gas stream. In a typical power plant the stack design is usually predicated on achieving acceptable sulphur dioxide concentrations but incidentally the stack affects proportionately the concentrations of sulphur trioxide, the nitrogen oxides and the small amount of flyash remaining after conventional gas cleaning.

VI. TECHNICAL PROBLEMS REMAIN, BUT THEY DO NOT CONCERN THE MAJOR EFFECTS OF STACKS

As I pointed out in my National Conference paper, there are many technical questions and controversies remaining about the effectiveness of stacks. We have much to learn about the effects of terrain and city buildings on stack gas behavior and we are just beginning to understand the atmospheric chemistry of many pollutants, but I do not believe that the major benefits associated with tall stacks are debatable. Perhaps the most telling point I can make is to assure you of my conviction that the vast majority of organizations using fossil fuels in large quantities would continue to use stacks even if the sulphur content of all fuel were reduced to 10% of current levels overnight, and even if our regulatory standards were based solely on amounts emitted. The new stacks might be shorter, but and the small amount of fly ash remaining after conventional gas cleaning.

VII. REGULATORY STANDARDS SHOULD CONSIDER VARIATIONS IN ENVIRONMENTAL CONDITIONS AND CONDITIONS OF RELEASE

Having worked with air pollution problems for 20 years, it is easy for me to appreciate the appeal of an "across-the-board" emission standard. It is far easier to design and administrate than a complex system involving additional considerations. I feel, however, that just and effective standards must take account of the circumstances of release and of the local environmental conditions, espe-

cially in regard to very large, individual sources. Failure to include these factors would mean that we are capriciously discarding some of our most effective technology in the fight against air pollution.

My conclusion is that any legislation on air pollution should recognize the utility of high stacks and include consideration of the topography, meteorological conditions and source characteristics of the region. Local or regional regulations which take into account specialized problems of very large individual sources are clearly preferable to uniform national limitations of emissions.

Senator MUSKIE. I take it from your testimony, and I am now speaking generally for the three of you, that you are not satisfied that your industry is doing a good enough job in dealing with air pollution, but that the testimony is directed at the most effective means for improving the performance. Am I correct?

Mr. FRANKENBERG. Yes, sir.

Mr. SMITH. I think so.

Mr. FRANKENBERG. I was very interested to note your reference earlier to the difference between the new plant that you built at today's level of the technology and the one built 15 years ago that perhaps has another 20 years useful economic life ahead of it and the tremendous additional cost to bring that one up to today's standard.

Senator MUSKIE. I was going to ask that question in due course.

Can you supply for us any figures on what the difference might be in converting an older mill to the same standard of performance, say it is an optimum standard that you could build into a new plant? Can you give us any idea of the order of magnitude here that might be helpful?

Mr. FRANKENBERG. As compared to doing it the first time or the cost of doing it now?

Senator MUSKIE. I don't know if there is such a thing as a typical over-plant, but taking an over-plant and comparing the cost of bringing it up to the optimum performance possible with current technology as compared to building the same technology into a new plant.

Is this kind of comparison possible to portray?

Mr. FRANKENBERG. Well, there are certain costs in there that are pretty hard to come at but we face exactly the same situation you are talking about at one of our plants in the Kanawha River Valley.

There is the so-called West Virginia regulation which was put in effect about a year ago and we face the problem of bringing up the dust collecting efficiency on that plant from its present level to about 98½. We have just gone through the cost to do this, and just for the dust collector equipment and the changes in the breaching and so forth, it looks like it will be about $2.5 million.

Some of it is a straight-out duplication of the existing installation because we have these present dust collectors up on the roof of the plant, but to get to 98½ they need to be about two and a half times as big as they are now, physically straight body. Therefore, there is not the steel to hold them up; there is not the roof area to put them on.

What we have visualized doing is to leave the existing ones there, come out of the present stack, run up to the north end of the plant, drop down into new dust collectors which will be very big ones. In order to save some space, we will put them one above the other and then out into a new stack because it would be more expensive to try to go back and use existing stacks on the building than it would be to put a new one on the ground there.

Now, I guess your question is how much would it cost you to do this in the first place? The dust collector would cost exactly the same amount. You would probably not have the cost of new foundations for it because you would somehow put them into the new foundation as a whole new plant.

The duct work would certainly be a lot less expensive when you simply flared out from behind the boiler to your new dust collector instead of having to take this detour to the north end of the plant.

Senator MUSKIE. Now, it seemed to me that electrostatic precipitators, ought to be required equipment on all of these plants wherever they are located.

Mr. FRANKENBERG. This is exactly what we are doing now.

Senator MUSKIE. Isn't this the basis for a national standard?

Mr. AVILA. No. They have been burning almost all coal. On the eastern seaboard, they burn oil. Preciptators for oil have not been available. There is work being done in one or two installations but there is extreme danger of fire and explosion from the soot.

Senator MUSKIE. Why should we not require an all-coal fired generated plant?

Mr. SMITH. Senator, I think one point that you might make there is yes, it could be required of all coal plants but you don't stop at just saying it is required; you are going to put it on percentage as well. I think we are right back at what you were discussing earlier today, should this percentage vary? Yes.

Senator MUSKIE. I gathered from the steel industry testimony yesterday that 95 percent is one level of effort and cost and 98 or 99 is another level and the difference is a substantial difference in cost.

Why not require at least 95-percent control of particulates by coal fire generated plants?

Mr. FRANKENBERG. Well, that is what I was about to say.

In the area where we burn coal, we have not put in a plant since 1960, I believe is the date, that has not had at least 95 percent collective efficiency.

Senator MUSKIE. Now, it seems to me this may be what the Public Health Service has in mind in connection with national emission standards. In other words, the industry recognizes that the kind of control is desirable wherever such a plant is located.

Mr. FRANKENBERG. This is essentially what we said in a paper to the National Air Pollution Conference in 1962, that we felt that the industry had pretty well committed itself to the reduction of the particulate burden in the escaping gas.

Senator MUSKIE. This has been done without a positive finding of the deleterious effect upon the ambient air quality in the hundreds of communities that may be involved across the country.

Mr. FRANKENBERG. That is right.

Senator MUSKIE. In other words, you have decided that because of the nature of this kind of emission it ought to be controlled.

Mr. FRANKENBERG. That is right.

Senator MUSKIE. Isn't it conceivable that a similar finding could be made with respect to other kinds of pollutants and that as the technology is developed and is proven out in terms of economic and technological feasibility, it ought to be applied on a national basis to particular industries?

Mr. FRANKENBERG. I believe the key word is when it is proven out in economics.

Senator MUSKIE. The proposal in the legislation has that language and we could tighten it up. I think that is the general concept in laymen's terms that is being aimed at here.

Of course, in your industry you don't have the competitive situation which generates the kind of economic threat that underlies some of these problems in some communities. Boston Edison is going to be staying in your area to generate electrical energy for the New England area; you are not going to move to the midwest to do the same job.

Mr. AVILA. I would like to object that we don't have competition.

Senator MUSKIE. We are trying to create competition.

Mr. AVILA. I mean even in the area we have competition with gas or, say, the house heating so we are not without—in other words, we are not free to have a rate irrespective of cost.

Senator MUSKIE. What I had in mind was the kind of competitive pressures that might prompt you to move from one region to another.

Mr. AVILA. That is true, or in one area where you have different standards competing with another.

Senator MUSKIE. So that consideration is not involved in your reaction to this proposal. It might be in other industries.

Mr. FRANKENBERG. We do think, though, in terms of the ultimate effect on the consumer and how much this might be.

Since we are in the position of being a franchised business in an area, he is a customer who can't move away too readily. His job, as a residential customers, is in that area. If he is in industry that serves the area, he can't move away.

Senator MUSKIE. I understand. I understand that point.

Mr. FRANKENBERG. We are not anxious to——

Seantor MUSKIE. We don't want to move him out of New England, either.

Mr. FRANKENBERG. This history of having the rates decline is a wonderful history to have behind the industry.

Senator MUSKIE. I would like to ask just two more questions and then I am going to have to turn to the other witnesses.

I guess I was not here yesterday when this witness testified, but one of the witnesses yesterday suggested that with some of the sulfur controlled processes it would be more economical to control sulfur emissions when high sulfur coals are used.

Do you want to comment on that?

Mr. AVILA. I think that was on the theory if there was a net gain by the sale of sulfur, then obviously a high sulfur coal might give you more of the product but this is on the assumption that the process is revenue, is an expense. I think his theory was if we could get to that point, then you would be delighted to have high sulfur fuel because this would be better.

Senator MUSKIE. I see.

Now, yesterday we had testimony dealing with several processes for dealing with the sulfur problem in flue gases, alkalized alumina process, the catalytic oxidation process, the Bechtel process, that involves desulfurization and the char oil energy development.

With respect to the first three, do you, as an industry, have any reac-

tion as to their feasibility, as to the eminence of the breakthrough, the applicability to their industry and so on, or would you like to submit that kind of analysis for the record?

Mr. FRANKENBERG. I would like to comment.

We have looked at these. I have sat on a steering committee with BCR people for about 4 years and none of the methods that have been put forward so far seem to have any hope of economic feasibility.

Senator MUSKIE. The dolomite process, for example, seems to be just reaching a viable point where it might be a viable answer to the problem.

I think they testified that they are ready to go to the pilot plant stage. Have you followed it up to this point sufficiently so that you feel competent to answer? Do you have an up-to-the-minute reaction to it?

Mr. FRANKENBERG. I know of their work at Detroit Edison. I have discussed it some with people from Detroit Edison. It seems to me that for many utilities it will pose a great problem.

You have to add roughly as much limestone as there is ash in the coal, so you have doubled your problems of disposing of the ash.

I know that the proponents of this are very hopeful that it will become economic. I think we will have to wait until this pilot plant is actually in operation to see what it does.

Senator MUSKIE. The prospects seemed quite certain yesterday. I suppose it would be a difference in reaction, sort of a proprietary interest.

Mr. FRANKENBERG. Well, if you are going to develop a process, you want to have optimistic people behind it.

Senator MUSKIE. That is the kind of optimism we are trying to generate.

Thank you, gentlemen.

There are other things I would like to ask but we do want to finish by 1 o'clock.

Mr. AVILA. Thank you.

Senator MUSKIE. Senator Proxmire has sent this committee a letter from W. A. Pollock of the Wisconsin Electric Power Co. It will appear at this point in the record.

(The letter referred to is as follows:)

WISCONSIN ELECTRIC POWER CO.,
Milwaukee, Wis., April 18, 1967.

Re Senate bill 780.

Hon. WILLIAM PROXMIRE,
Senate Office Building
Washington, D.C.

DEAR SENATOR PROXMIRE: On February 27, 1967, I acknowledged your letter of February 14 regarding Senator Muskie's air pollution control legislation S 780. You will recall that you wrote me asking for my suggestions as to amendments to the administration's legislation to make them more in accord with the thinking of the Milwaukee County Air Pollution Control Dept. Advisory Board of which I am chairman. Our board met on April 7 and discussed this legislation in detail. I will try to summarize our conclusions.

We recommend that (1) State and local authorities be created and subsidized as necessary in lieu of further Federal conrtol, (2) Federal resources be expended on research of methods of prevention of air pollution and on its health effects, (3) Air quality criteria if established at all be regional and not national in scope, (4) Automotive pollution control be divorced from road building programs, (5) Consideration of legislation should take into account its effect on

the economy of the nation, and (6) Reasonable limitations be adopted which at least a portion of industry can meet or for which equipment or fuel is economically available as opposed to limitations which cannot be enforced. Because HEW has not implemented the programs already authorized by 1963 legislation, it is not ready for new programs.

DISCUSSION

Public Law 88–206—The Clean Air Act—was signed into law on December 17, 1963.

Section 101 (a) (3) states:

"The Congress finds—(3) that the prevention and control of air pollution at its source is the primary responsibility of states and local governments."

To this we wholeheartedly subscribe. And we add—that due to the diversity of the facts that should be considered in setting emission standards, the setting of such standards are best handled locally. Some of these factors include:

(a) Present air quality of a community.

(b) Local meterology.

(c) Local topography.

(d) Industrial makeup of community.

(e) Economic impact on community. How much is a community willing *or able* to pay for clean air.

(f) Present technology.

P.L. 88–206 presently prescribes in Section 105 for a proper and significant Federal role in air pollution problems that are international, interstate and intrastate in character. We believe that there is no further need *at this time* to expand the Federal authority as provided in Section 5—Industrial Emission Standards, in adding Section 107 of HR 4279 and S 780.

The authority for the Secretary of HEW to act in international, interstate and intrastate matters has existed since December 17, 1963 but it was not until January 17, 1966 that the *first* recommendations or orders were issued by the Secretary in a matter of interstate air pollution. This would indicate that HEW has not had sufficient time to determine the effectiveness, or ineffectiveness, of its present authority.

S 780 goes much too far in setting up controls. If the first two objectives stated in the purpose of the bill, namely "to improve and expand authority to conduct or assist research relating to air pollutants" and "to assist in the establishment of regional air quality commissions" were adopted and the last objective modified "to assist in establishment and maintenance of State and local programs for air programs for *air pollution control departments*", the public would be better served.

Establishment of State motor vehicle inspection programs by S 780 as a condition of approval for certain Federal aids exerts undue pressure to adopt criteria which are "suggested" without adequate consideration of what is needed in the locality involved. Further, any compulsory State motor vehicle inspection program must be accompanied by sufficient Federal funding to support such a program. Federal requirements for antismog devices which have been proven inadequate and in some cases worse than none is ill advised. We agree that the automobile deserves prime attention in any air pollution control program. USPHS reports motor vehicles are responsible for 64 percent of today's pollution, with manufacturing responsible for 17 percent, public utilities for 11 percent, domestic heating and waste incineration 8 percent.

The controversial Air Quality Criteria for Sulfur Dioxide released by the USPHS after months of debate is admittedly based on "effects empirically obtained" and not on experimental data. This is a place where research into tolerance limits of sulfur compounds separate and in combination with other substances is necessary to intelligently establish acceptable air quality criteria. The proposed sulfur oxide criteria cannot be met by manufacturing and utility industries. There is not enough low sulfur coal and heavy oil available to meet the needs and even though industries and educational institutions are expending millions of dollars in research, a practical means has not been developed to either remove sulfur from the fuel or sulfur products from the exhaust gases of processes. Should the Federal regulations which restrict fuels burned in government operated facilities be extended to industry, the coal fields of Illinois, West Kentucky, Ohio, and elsewhere will be closed down creating new areas equivalent to Appalachia.

We appreciate this opportunity to communicate our thoughts on this vital issue. We will supplement these comments if this is found advisable. Please keep us advised of future developments in this area.

Respectfully,

W. A. POLLOCK,
Chairman, Milwaukee County Advisory Board on Air Pollution.

Senator MUSKIE. Our next witness is Mr. Jerome Wilkenfeld, Air Quality Committee, Manufacturing Chemists Association.

STATEMENT OF JEROME WILKENFELD, MANUFACTURING CHEMISTS ASSOCIATION; ACCOMPANIED BY EMMET F. SPENCER, JR.

Mr. WILKENFELD. My name is Jerome Wilkenfeld. I am here to testify on behalf of the Manufacturing Chemists Association (MCA) a nonprofit trade association of 189 U.S. corporations, large and small, that collectively represent more than 90 percent of the productive capacity of the basic chemical manufacturing industry in this country. I am professionally employed by a major chemical company as director of environmental health, and am currently serving as chairman of the MCA Air Quality Committee. Accompanying me is Emmet F. Spencer, Jr., pollution control engineer for another member company of the association who has special background and experience in industrial air pollution control.

We would like to preface our remarks on research and technology of air pollution control in the chemical industry with three points of philosophy that are relevant and worthy of emphasis.

First, there is no basis for presuming that any and all substances emitted to the atmosphere are necessarily detrimental, no matter how small the amount. The tang of the ocean breeze, so highly regarded by many, is due in large part to aerosols of sodium chloride, magnesium chloride, traces of organic matter and other chemicals suspended in the marine atmosphere. A complex mixture of volatile chemicals that we classify as terpenes, when present in the air over our northern forests, is not regarded as "air pollution," but rather is prized for the piny scent characteristic of those regions. The refreshing character of the air after a summer thundershower is not lessened by the increased concentrations of oxides of nitrogen and ozone produced in the lightning flashes.

We do not wish to belabor this point with tediously iterated examples.

Senator MUSKIE. What you are telling me is that the air in Maine is polluted?

Mr. WILKENFELD. Senator Muskie, I am telling you just the opposite; the air in Maine is excellent and vigorating. This is the point we are trying to make, to point up the difference between pollution and trace contamination.

Those examples given clearly demonstrate that the addition of a chemical substance to the air does not necessarily detract from the quality of the environment or its full enjoyment by its inhabitants. The fundamental consideration is whether the effects produced by these chemicals, at the concentrations present in the atmosphere, create an air quality that is not desired by those who live in it.

Second, control programs administering appropriately established ambient air quality standards should not be regarded as "licensing limited pollution" or "allowing the air to be as dirty as we can stand it." Air quality criteria are scientifically determined cause-and-effect relationships, and ambient air quality standards should be adopted, taking the applicable criteria into account, that will control unwanted effects. This having been achieved, "pollution" no longer exists, since by definition pollution represents an unacceptable condition of adverse effect.

Third, the earth's air envelope should not be regarded as a static atmospheric sink, into which an ever-increasing amount of foreign matter is being poured, there to remain and accumulate until it reaches intolerable levels. Data on large tonnages of substances emitted nationwide are often discussed as though this were the case. While its mechanisms are as yet incompletely understood, there is no doubt that atmospheric clearance does occur. With the possible exception of carbon dioxide, there is little evidence of long-term progressive accumulation of any contaminants in the atmosphere.

At any given rate of emissions, a pseudo "steady state" is achieved wherein discharges to the atmosphere are in balance with the rate of removal by the natural self-purification processes. If this steady state balance occurs at a level below that at which adverse effects result, there is no pollution. Efforts devoted to reductions of emissions below this point must be recognized as diversions of funding and manpower from significant pollution control endeavors.

Although we realize that the chemistry of the atmosphere is a highly complex subject and that our association's contributions to knowledge in this area will have to be limited, we acknowledge an obligation to learn more about the fate of chemicals released into the air—their interactions and the mechanisms of ultimate removal. In the coming year, we will be initiating association-funded research activity along this line, and believe this to be an appropriate area for more research attention by governmental agencies as well.

Air pollution control, we believe, should be purposefully planned to meet regional objectives. Just as people should not be expected to forego outdoor barbecues or indoor fireplaces—both of which give rise to smoke—unless these personal activities make for offense to the community—as home incinerators did in Los Angeles—so should industrialists not be expected to apply all available technology in the absence of demonstrated need. The overall economic burden of air pollution control will be necessarily huge at best; it should not be unnecessarily augmented.

Turning now to the chemical industry and the status of its technology in controlling air pollution, we face the dilemma of trying to generalize in a matter that defies generalization.

This is not to say that air pollution controls for most chemical manufacturing operations are necessarily complex—indeed, many are quite simple—but they present an almost infinite variety.

The number of chemicals commercially produced reaches into the thousands, each having its particular variants in the manufacturing process. Not all involve atmospheric emissions; in fact, a survey by MCA in 1962—now being updated—revealed that 33 percent of the

nearly 8,300 processes in use at 879 reporting plants had no routine discharges of gases, mists, or dusts to the atmosphere. A process was defined as a set of unit operations carried out in an integrated group of equipment, producing one product or a number of kindred products, simultaneously or at different times.

Many processes, of course, do call for special attention to atmospheric controls. Actually, in view of the relatively hazardous character of certain chemicals, producers were paying great heed long before the term, "air pollution," became a familiar one. The excellent industrial health and safety record of the chemical industry testifies to the care which has been taken. Chlorine, for example, produced at the rate of more than 6 million tons a year, and upon which we rely so heavily for purification of our drinking water, would create intolerable working conditions in plants where it is manufactured if thorough precautions were not taken to prevent its release.

MCA is encouraging the development of more complete documentation of industrial working environments, particularly as guidance for industrial hygiene considerations, but in the hope that such information will be helpfully indicative for general air pollution purposes. also.

Similarly, our association is in joint sponsorship with four other trade associations of a research project on emphysema being carried on by the Industrial Hygiene Foundation of America, to explore whether airborne particulates or gases influence either the onset or the cause of this lung disease.

The air pollution control measures applied in chemical manufacturing are for the most part simply the everyday application of chemical engineering unit operations, utilizing mechanical filters, inertial and electrical collectors, wet scrubbers using spray towers or packed columns, catalytic oxidation or reduction units or absorbers—alone or in combination.

The selection of control equipment that will solve the problem, at the lowest cost consistent with the desired results, is an engineering design problem of matching the performance characteristics of the available devices against the nature of the effluent and the required degree of control. Two manufacturers using essentially the same process may elect to use different means of emission control.

More importantly—and this is the preferred route wherever practicable—process or equipment modifications may be specifically incorporated to minimize the extent of treatment necessary for the emissions. Thus the control device alone may not fully indicate the attention given to air pollution control. While this is often true for other industries as well, it is particularly characteristic of chemicals manufacturing.

There is a growing body of technical literature about industrial emissions to the atmosphere and their control. Since 1962, MCA has been engaged in a cooperative study with the Public Health Service on atmospheric emissions from selected chemical manufacturing processes and the performance of devices in use to control these emissions. Two reports have been published from this work, one concerning sulfuric acid and the other nitric acid. Similar studies on both wet and dry process phosphoric acid, hydrochloric acid, and chlorine-caustic soda are currently in progress.

Search continues within the chemical industry to develop improved and less costly techniques for air pollution control. In the 1962 survey, previously referred to, 125 member companies of our association reported their pollution research amounting to $2.8 million annually.

Beyond solving the problems incident to their own manufacturing operations, chemical producers are alert to the future market potential of control techniques applied elsewhere in this field, and we are confident that the profit motive will be a helpful stimulus to progress.

We see no problem of air pollution control technology specific to the manufacture of chemicals that is beyond the industry's capability of satisfactory solution, within a framework of reasonable and proper regulations. In some instances, the time schedule for accomplishment will be an important factor, and we shall always be interested in lowering the costs involved.

We recognize that some chemical plants do have an odor problem that can constitute a community annoyance. MCA is currently sponsoring a project to obtain reliable odor threshold data for a sizable group of odorous chemicals. Such data will assist engineers in defining the degree of process and emission control required to prevent or abate these problems.

Another area meriting additional attention, from the air pollution standpoint, is better control of the incineration or other disposal of solid wastes. One attack on this problem, as reported in "Recent Combustion Developments Prevent Air Pollution" by E. S. Monroe, Jr., E. I. du Pont de Nemours & Co., yielded an open-top incinerator of novel design employing a bank of air jets to obtain smokeless combustion of a variety of waste solids. There is a small bulletin that has been written on this and we can leave it for the record if you desire.

Senator MUSKIE. It will be included in the record.

(The document is as follows:)

RECENT COMBUSTION DEVELOPMENTS PREVENT AIR POLLUTION

LOW EXCESS AIR FIRING OF HEAVY FUEL OILS AND NEW WASTE INCINERATOR

(By E. S. Monroe, Jr., before Joint Technical Conference on Clean Air, sponsored by Delaware Valley, New Jersey and Metropolitan New York Sections of the American Industrial Hygiene Association and the Mid-Atlantic States Section of the Air Pollution Control Association in Trenton, New Jersey, on November 19, 1964)

This morning I would like to discuss with you two fairly new developments in combustion that have an influence on the work of the Air Pollution Control Association and the American Industrial Hygiene Association. They are, first, the stoichiometric or low excess air firing of heavy fuel oils and, second, a newly developed incinerator that combines simplicity and low cost with high performance.

Perhaps these subjects sound a little farfetched to you, but they are both realities that have been demonstrated in operation to be of significant benefit in the areas of air pollution abatement.

I am not sure that I know what your definition of air pollution might be since my work is primarily in the area of powerhouse operation. I do know certain established limits on stack color and emissions, but I think my Company's insistence on being a good neighbor is the best guide that I have. Rightly or wrongly, when the neighbors around a plant complain of nuisances, we feel that we have an air pollution problem.

One of the most difficult problems that we have had, as have others, is the burning of heavy fuel oil in boilers. It is not at all difficult to keep a clear stack that is pleasing to the eye, but eventually there comes a time when the boiler

must be soot-blown if it is to be kept in operation. The resulting fallout of large, oily soot particles can generate considerable neighborhood feedback of complaints.

Unfortunately, it now turns out that in keeping our stacks clear with copious quantities of excess air for burning the heavy oil, the soot problem has been aggravated. In 1962, reports reached the U.S. that F. Glaubitz,[1] of the Emsland Refinery in Germany, had operated a boiler burning heavy fuel oil over 4,000 hours without soot blowing and that high efficiencies were maintained. They have now passed 35,000 hours and are doing this by approaching stoichiometric combustion, or burning with theoretical amounts of air without smoke or unburned fuel. Although technical reports had contained intimations of this feature before, they were generally buried and well hedged. But here was a man who had done something outstanding as an accomplished fact.

I became an instant disciple of Herr Glaubitz and had one advantage. While he had to start from scratch to develop a suitable fuel oil burner, I knew where Du Pont had one in service. Accordingly, early in 1963 we ran a 32-hour test on a 40,000 lb./hr. package boiler, keeping the excess air at about 1%. Fifteen percent excess air is usually regarded as minimum and 30% is common. Sure enough, flue gas temperatures remained steady, indicating little fouling, and at the end of the test a thorough period of soot blowing produced negligible soot. The control of the boiler during the test period was manual since the automatic controls that were installed were not capable of such operation.

After discussion with manufacturers, the controls on two identical boilers at one of our New Jersey plants were rebuilt during the summer of 1963 to operate automatically with controlled low excess air. These boilers were equipped with heavy-oil burners capable of good performance with as little as 1% excess air in the flue gas. One boiler was operated during the past year at about 7% excess air while the other was operated with 15% as a comparison. Both boilers were soot-blown on the same regular schedule, but the lower excess air boiler consistently produced little soot.

At the annual inspections this summer, the tubes of the first boiler were clean and coated only with a thin, dry white powder, while the second boiler was covered with the usual heavy hydroscopic and acidic covering of black soot. The second boiler required water washing while the first boiler did not. The controls were modified further this summer, and during the coming year, it is planned to operate both boilers at 2½% excess air.

Much research work is being done on the technical aspects of this method of firing by Battelle Memorial Institute[2] under the auspices of the ASME Esso Research and the major public utilities in the New York area are also active. Briefly, the benefits are these.

ADVANTAGES OF STOICHIOMETRIC COMBUSTION

1. Reduced Soot Blowing
2. Reduced SO_3
3. Reduced NO_2
4. Reduced Fuel Consumption
5. Reduced Corrosion and Pluggage

As you can see, there is something for everybody in the stoichiometric combustion of heavy fuel oil. Achievement on a national scale will not be easy since many existing burners and furnaces are not capable of low excess air operation. Other factors, such as sulfur content of the fuel oil and furnace temperatures, are also significant in the amount of soot produced. Controls must be carefully engineered. Last, and not least, the operating concept that heavy fuel oil burning requires at least 15% excess air is not easy to overcome. You people must also become convinced that a slightly visible stack discharge (less than No. 1 Ringelmann)—the so-called efficiency haze—is a desirable situation. Convincing the average housewife is going to be even more difficult.

While little publicized to date, experience and knowledge are beginning to grow fast and, in the not too distant future, I can foresee many installations which

[1] "The Economic Combustion of Sulfur-containing Heating Oil", F. Glaubitz, Mitteilungen Der V.G.B. Heft 68, October, 1960. Reprinted in English in January, 1963, and March, 1963, issues of *Combustion*.

[2] "A Progress Report—Fundamentals of Thermochemical Corrosion Reactions", A. Levy and E. L. Merryman, ASME Paper No. 63–WA–107.

will be better neighbors since they will limit the allowable excess air for burning heavy residual fuel oils. Development in coal burning installations is sure to follow.

NEW WASTE INCINERATOR

For our second discussion on a new combustion development, we turn to waste incinerators. In Du Pont, we call them chemical waste destructors since, frequently, harmful and toxic wastes are converted to harmless gases. These incinerators do not produce revenue. They represent large investments and operating costs which are necessary for good neighborhood relations and pollution requirements.

Because we had a requirement at a plant to burn waste nitrocellulose, we built an experimental open top incinerator of novel design. A conventional enclosed incinerator was not judged feasible because of the explosion hazard.

The principal feature of this unit, other than its open top, is the admission of all air for burning through closely spaced, high velocity nozzles. This unit proved to have exceptionally good combustion characteristics. Burning rates were found to be almost double those obtainable with conventional designs. The air jets produce a cylindrical rolling flame that has adequate time to complete combustion. Flame temperatures are high and turbulence or mixing of the air and fuel are enhanced. As a result, combustion is complete and thorough.

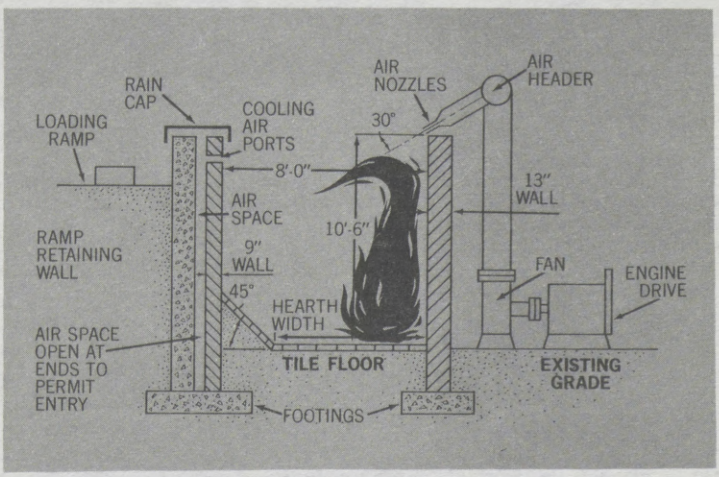


FIGURE 1

Many solid and liquid wastes have been test-burned satisfactorily, including such items as paper, wood, rubber, paint, synthetic fibers, films, and plastics. Each material requires careful attention to design criteria for optimum results. When these have been properly applied, results have been consistently good. In all cases, the waste has been reduced by complete combustion of all possible material with only metals and ash particles remaining in the furnace. Since these are normally of small magnitude, infrequent cleaning has been necessary and is easily performed through a small access door in one end or by mechanical means from the top.

The open top has a number of advantages. Not only does it make simplified material handling possible for loading or cleaning, but it eliminates costly roof maintenance. Through proper geometric configuration, the open top also overcomes one of the major reasons for high maintenance with conventional units—that of refractory damage from excessive temperatures. The open top serves as a radiating surface to the sky and limits the maximum attainable temperature.

Figure 2 shows the calculated temperatures for a film waste. Our test unit has only 4½-inch firebrick walls which have stood up excellently under considerable abuse for over a year.

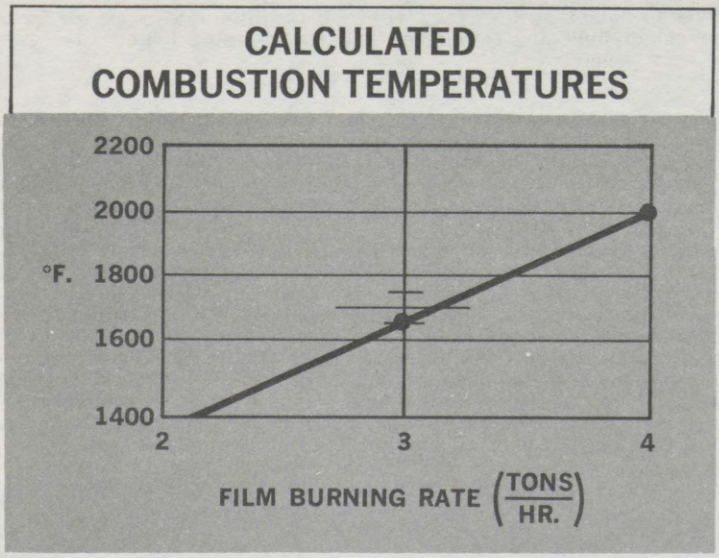


FIGURE 2

Figure 3 shows the criteria for design of suitable units. It is essential to know the highest heating value of any waste to be burned. If various wastes are to be handled, a dual manifold is desirable so that the air supply can be reduced on one without reducing the jet velocity on the other.

DESIGN CRITERIA FOR TRENCH INCINERATORS

1. See figure 1 for cross sections.
2. Length (ft.) =

$$\text{Waste (lb./hr.)} \times \text{HHV} \left(\frac{\text{BTU}}{\text{LB.}}\right) \times \frac{1}{3.4\,(10)^6}$$

3. Hearth Width (ft.) =

$$\frac{(84{,}000)}{(\text{HHV})\ (\text{BTU/LB.})} \quad (\text{Max.} = 8\ \text{ft.})$$

4. Air Supply (CFM) = 850 x (Length)
5. Air Supply Pressure = 10 inches of H_2O SP
6. Nozzle Arrangement = 2 or 3 Inch Diameter Spaced to Suit.

FIGURE 3

If the waste is extremely volatile, it is best to feed it constantly as with any unit. If paper or film is to be burned, a screen cage over the unit is also desirable to retain any discharge that escapes the jets.

A final word is in order with regard to investment and operating costs. The reduction in size through high burning rates and the simplified construction consisting of a firebrick-lined pit result in obvious economies. We have found them to be of considerable magnitude. In addition, operation is simple and requires a minimum of unskilled labor. The simplified materials handling is also an asset.

In summary, I have shown you two new methods of improved combustion which can contribute to reduced air pollution: Stoichiometric combustion for heavy fuel oil, and a simplified overfire air-jet system for pit incinerators. Both of these systems excel in performance and economy and their rapid adoption will be to the mutual advantage of industry and the public.

Mr. WILKENFELD. MCA committee efforts will be directed to air pollution control and to other aspects of solid waste disposal.

As a large fuel consumer the chemical industry shares in the problem of limiting sulfur oxides emissions. It is our understanding that information on one approach to sulfur dioxide removal from fuel combustion products is being presented during the course of these hearings by a representative of the Monsanto Co. And similarly, FMC Corp. is reporting on a project concerned with the removal of sulfur from coal. These projects exemplify attention by chemical companies to problems that extend beyond their own manufacturing operations.

Now, in closing, may I direct my remarks to the question put to me on May 8 by Senator Muskie, relative to the impact of Government patent policy on the willingness of the chemical industry to accept Federal sponsorship for air pollution control research.

Where a firm has already established a proprietary position in a field as a result of corporate-funded research, there is likely to be some reluctance to accept Government funds for research where such action might compromise patent rights to the fruits of the research.

Generally speaking, however, this factor is not believed to constitute a significant barrier to participation in federally funded programs by the chemical industry.

MCA now has member companies receiving support from the Federal Water Pollution Control Administration for research and development in that field. Additional members of our association have indicated a desire to participate in the air pollution research effort.

In the last Congress, Senator McClellan introduced S. 1809 to establish a uniform Government patent policy. This bill provided that the Government would take principal patent rights to inventions directly concerning public health, safety, and welfare, a classification into which we would expect most pollution control inventions might fall.

MCA testified in support of the provisions of this bill in June 1965. While our industry would like to see legislation enacted establishing a uniform Government patent policy such as proposed therein, it is not believed that the present patent situation is a major deterrent to chemical industry participation.

Thank you for this further opportunity to take part in these hearings.

Senator MUSKIE. In your testimony you referred to two reports that have been published, one concerning sulfuric acid and the other nitric acid.

Do you think those reports are pertinent to these hearings?

Mr. WILKENFELD. They are quite extensive. We have copies of them here and can leave them for the committee, if you wish. They are rather extensive and would add quite a bit of bulk to the hearing record. I will leave it to the judgment of the committee.

I think the staff and the Senators will find them interesting in that they indicate the extent and range of emissions that can be expected from typical sulfuric acid plants both by inventory and by actual sampling. All this was done on a voluntary basis by industry in conjunction with the Public Health Service.

Senator MUSKIE. On page 5 of your testimony you make this statement:

> Many processes, of course, do call for special attention to atmospheric controls. Actually, in view of the relatively hazardous character of certain chemicals, producers were paying great heed long before the term "air pollution" became a familiar one.

It seems to me there is implicit in this statement exactly what the administration is saying as justification for a national emission standard with particular industries when such hazard is identified.

Now, would you disagree with that completely? It does not necessarily follow if you start with the same premise that you have the same result.

Mr. WILKENFELD. I don't draw the same conclusions.

My understanding of the situation is this, that what this demonstrates is the responsibleness of the industry many years prior to any regulatory requirement for control.

Senator MUSKIE. That is not the part of the statement I was focusing on, Mr. Wilkenfeld.

I was focusing on these two points: One, you say many processes, of course, do call for special attention to atmospheric controls.

Mr. WILKENFELD. That is right.

Senator MUSKIE. The Public Health Service has made that same statement as a partial justification for its approach to the problems.

Secondly, you say that certain chemicals had a relatively hazardous character and the Public Health Service has said this, too.

Mr. WILKENFELD. That is right.

Taken in the overall context, these materials can be very hazardous in certain concentrations or in certain quantities or in certain exposures.

We recognize the hazard of these materials under certain circumstances in handling and use, and we feel that control is necessary. We don't object to the fact that the ultimate control of air pollution has got to be at the source. It is the method of developing what control is required and the degree of control for different sources where we feel variation occurs.

We think that in talking about air pollution, the primary point of determination of need has to be at the community level, the ambient air as it has come to be known.

Senator MUSKIE. Is this what you are saying on page 5?

You are saying that many processes, I assume, do call for special attention to atmospheric controls because of their hazardous character.

The Public Health Service has said that when this is determined and when the technology which meets the test of economic feasibility is de-

veloped, it ought to apply wherever such a process is located. Now, you seem to be saying that there are such processes. What you do about it is where you quarrel with the Public Health Service, but you are saying that there are such processes.

Mr. WILKENFELD. I agree. When it is determined that if these are causing air pollution; that is, affecting adversely the quality of the ambient air, then controls must be applied, but where I differ——

Senator MUSKIE. Wait.

Mr. WILKENFELD. Let me continue a moment, sir.

Senator MUSKIE. All right.

You want to slide over what to me is the critical point.

Mr. WILKENFELD. If I do, you bring me right back to it. I am sure you will.

What I am saying is that when it has been determined that the ambient air is exceeding what is considered acceptable, then the need for control will have been established, but the degree of control may vary quite considerably from one location where an ambient air standard is exceeded to another, dependent on many factors which were mentioned several times this morning, and this is where the difference occurs. That is our feeling, that a uniform emission standard does not apply.

Now, the definition of a uniform emission standard that was given this morning by Dr. Middleton is considerably different than what I understood it to be in the past.

Senator MUSKIE. Now let me bring you back.

Mr. WILKENFELD. All right.

Senator MUSKIE. It seems to me that on page 5 you eliminate the "if". You say, "Many processes do call for special attention to atmospheric controls. Actually, in view of their relatively hazardous character * * *".

Now, what that says to me is that you don't have to make any finding as to the health effect of the ambient air of a particular community because these processes by their nature are sufficiently hazardous to require controls. That is what that language says to me.

Mr. WILKENFELD. Well, I think the key phrase here is "atmospheric controls", and what we mean by "atmospheric controls" is the controls over the emission.

I think the major point here is that we are not saying that a process which produces hazardous materials has to have the same degree of control in all locations.

Senator MUSKIE. This again is not the point that I am driving at. You are saying they need some control.

Mr. WILKENFELD. That is right.

Senator MUSKIE. All right.

Now we can proceed from these to argue what the control ought to be or how to apply it, but you are saying, and this is a very important point, I think, that there are some processes which by their nature are hazardous and ought to be controlled in some way.

You say, "We see no problem of air pollution control technology specific to the manufacturer of chemicals that is beyond the industry's capability of satisfactory solution, within a framework of reasonable and proper regulations."

Now, I take it that no one is deliberately proposing unreasonable and improper regulations.

Mr. WILKENFELD. I would hope so.

Senator MUSKIE. Not deliberately.

Mr. WILKENFELD. That is right.

Senator MUSKIE. Now, relate that to what you said on page 5 that there are some processes which by their hazardous nature ought to be controlled and that such control is within the industry's capability of satisfactory solution—is that correct?

Mr. WILKENFELD. Yes, but I think we are still a little bit—perhaps it is semantic in nature—but when we talk of hazardous materials, we talk of hazardous materials under certain specific circumstances and some of these can, if improperly controlled, cause difficulty in the community.

Senator MUSKIE. I understand all that.

Mr. WILKENFELD. All right.

We are not objecting to control that is necessary. On the other hand, I still come back to the point that a uniform national single emission standard, and I will differentiate from what Dr. Middleton said this morning, is not a proper method of control. If it is going to be at an absolute minimum level that will meet the test of the best situation—I am trying to decide whether the best or poorest—then the point becomes almost academic because it will only apply to that one place and every other place will have to have something more than that. So, you have not really gained anything.

Senator MUSKIE. Let me say this, and I want to narrow the point because of the pressure of time.

I suppose it is natural that when a Senator asks a question the witness tries to anticipate all the implications of the question, but really I am making a very narrow point. Perhaps I can focus on it this way.

If, in fact, as you say, there are processes which call for special attention because of their relatively hazardous character. If such hazards are being emitted by uncontrolled processes, does not somebody have responsibility for insuring that controls be applied as fast as the economically feasible technology is developed?

You are saying, as I take it, that industry can be depended upon to do that, but the fact is that the Public Health Service says that industry is not doing that as fast as the technology is being made available.

Now, if there are, in fact, such hazards, the responsibility for controlling them is being defaulted by industry, by local government, by State government. Isn't there responsibility on the part of somebody to do something about that?

Mr. WILKENFELD. Yes; there is a responsibility on the part of some level of government to do something. I think where we have some difference of opinion is what the approach to regulations should be.

Senator MUSKIE. Now, if we find as a committee that there are such hazards and your testimony helps us to move toward that finding, and if we find in addition that the control is defaulted, what, then, is our responsibility?

Mr. WILKENFELD. Your responsibility is to see that this country is protected to the best extent possible.

Senator MUSKIE. Now we have gone down the line of logic together.

Mr. SPENCER. Senator, I would like to add to this.

It is mentioned in the testimony that there are now some 8,300 different processes. In conjunction with the U.S. Public Health Service, we have been conducting these surveys on emissions from major industries with significant contributions where there are a number of competitors in the field. We come up with only six major, broad-scale industrial classifications.

Many of these processes that Mr. Wilkenfeld is referring to are in use by one company and at one place only; perhaps two or three hazards are recognized which usually have to do with toxicity considerations or flammability considerations.

I think the industry does recognize its responsibility to prepare the plants properly for their own protection, for their employees' protection, the community's protection. I think with the exception of a few broad-scale industries that these smaller processes should be handled by the companies, by the local officials at the local level.

Senator MUSKIE. Let me say this. I am not one to conclude that any industry is by nature oblivious or callous of the public interest involved in its operation. That is not the point, really. There probably are some, but I choose to believe that in our society those are going to be in the minority.

I think civic mindedness is a characteristic of Americans or else our kind of society would not have succeeded all of these years. There is the fact that there are some irresponsible people and callous people who won't meet public interest requirements.

Secondly, and this is the more important point, we are dealing with a subject on which there can be a difference of opinion.

Now, when there is a difference of opinion and when the public interest is so obviously involved, it seems to me that that difference of opinion ought to be resolved by an agency that is concerned not so much with the economics of its own interests, but with the public interest generally.

Those areas are not always easy to define and once you define them it is not always easy to come up with a kind of public policy to control. We recognize that. The hearing this morning demonstrates that I am concerned with it, but, nevertheless, I think that I am not trying to read too much into what you said here. In the excerpts of your testimony to which I referred, I think you put your finger on the nature of the concern which prompts the Public Health Service to advance S. 780 and which prompts us to give it serious consideration.

How it all comes out, I don't know. I used your statement as a means of pinpointing again what is troubling us.

Mr. WILKENFELD. I don't disagree with you at all, Senator on the need for regulatory control to take care of the recalcitrant few that will not do what is in the public interest. We all recognize this. There is a need for conciliation and persuasion and there is also a need for a strong regulatory power at certain times. The police power has to be behind control; I recognize this and know this from experience and we don't dispute it.

Senator MUSKIE. Senator Spong.

Senator SPONG. Did I understand you to say that of the 8,300 processes, we can identify those that are hazardous?

Mr. WILKENFELD. It depends on how we define hazardous. If it is clearly defined, we can dig out certain types of hazardous material but it does not necessarily mean that these are major polluters. We have to differentiate between what might be and what is. This is our business, the manufacture and handling of materials that are reactive and hazardous, and we are proud of our record in this field. We think we have done a good job.

We are always interested in learning where we can do better and learning from the public agencies where we are not performing as well as we should. No one should operate in a vacuum, oblivious to outside viewpoints how he is doing.

So, we are happy to work with the Public Health Service on these studies, to be sure that impartially we know what is going on in our industry.

Senator MUSKIE. Thank you, Mr. Wilkenfeld.

Mr. Kester, the last scheduled witness, is going over until tomorrow.

(Subsequently the following letter was submitted for the record:)

UNION CARBIDE CORP.,
New York, N.Y., May 17, 1967.

Senator EDMUND S. MUSKIE,
Chairman, Senate Subcommittee on Air and Water Pollution, New Senate Office Building, Washington, D.C.

DEAR SENATOR MUSKIE: We respectfully request that this letter be made a part of the record of the current hearings by your Sub-committee on S. 780 and on the proposed amendments to that bill and that it be considered by your Sub-committee in its deliberations.

Union Carbide Corporation manufactures chemicals, plastics, metal alloys, gases, carbon products and a number of other products. We have manufacturing plants, large and small, in 44 states.

We are writing to support four of the amendments to the Clean Air Act of 1963 which are being considered by your Sub-committee; and to oppose two of them.

Section 105 of the 1963 Act uses federal initiative to encourage state action against polluters in interstate pollution areas. This is done by federal conferences and hearings followed by recommendations for state action, with the ultimate alternative of federal action.

The *Air Quality Standard Amendment* (*Amdt. No. 154, Sec. 9*) will encourage the states, individually or by compact, to adopt ambient air quality standards for interstate pollution areas again with the alternative of standards established by the federal government. These standards will facilitate action against polluters and will provide enforcement agencies, industry and the courts with valuable guidelines.

Later in this letter we will propose modification of the enforcement procedure in this amendment to bring it fully in line with Sec. 105. *With such a modification we support this amendment.*

The *Regional Air Quality Commissions Amendments* (*one in S. 780 and the other in Amdt. No. 174*) will provide authority for the establishment of regular air quality commissions, regional air quality standards and regional emisson standards.

Again, with the modification proposed later in this letter to make it consistent with Sec. 105, we support the Regional Air Quality Commissions Amendment in Amdt. No. 174. It provides for independent regional commissions composed of state people nominated by the state and local governments with federal representation. It provides that standards established by the commissions are final, subject only to court review. It does not conflict with the Air Quality Standards Amend-

ment since it provides that the commission will be created only if the states fail to establish air quality standards, individually or under compacts.

We oppose the Regional Air Quality Commissions Amendment in S. 780. This amendment seems to reflect the view that state people cannot be relied upon to deal with pollution—a view that was rejected by the Congress in 1963 by an express finding in the Clean Air Act. It is a view which is even less tenable today. This and other objections have already been stated in the record of your committee's hearings.

The modification which we propose in the Air Quality Standards Amendment and the Regional Air Quality Commissions Amendment (Amdt. No. 174) is common to both of them. Both amendments provide for Federal injunction actions against polluters without specifically stating that such actions must follow the preliminary hearings and the opportunity for State action which Sec. 105 also provides. We see every advantage to the Federal enforcing agency as well as to the States and to the accused in making it clear that the full Sec. 105 procedure applies. We think that the preliminary hearing and the opportunity for State action are highly important features of that procedure. We think that uniform enforcement procedures under the different sections of the Act are important. We propose that the reference to "Sec. 105(e)" in each of these amendments be modified to read "Sec. 105" and that the amended Sec. 105 in Amendment 154, Sec. 8 be modified accordingly.

We oppose the Industrial Emission Standards Amendment (S. 780, Sec. 5). The case against national emission standards has been largely stated in the record of your Sub-committee's hearings and we do not need to repeat it. We think emission standards make sense and can be supported legally and constitutionally only where ambient air quality standards have been determined and the number of similar sources of a pollutant makes it possible to write a uniform emissions rule for those sources which can be reasonably calculated to achieve the ambient standards. We think that ambient standards cannot sensibly or legally go beyond health without taking benefits and costs into account and therefore must vary; and we think that emission standards will vary even if the ambient air standards are the same. The varying sulfur dioxide emission standards which the Department of Health, Education and Welfare recently set for federal institutions in New York City, Philadelphia and Chicago are good examples. The Department first determined an ambient air quality standard for all three cities based on health considerations, which it called an "Air Quality Criterion * * * drawn from studies of the adverse health effects of sulfur oxides at various * * * levels * * *." Then, to achieve and maintain this standard "the maximum emissions (standards) were derived individually for each area," since "the varying severity of the sulfur oxide problem in the designated areas * * * requires more restricted measures in the New York * * * area than in the other areas." The emission standard thus established in New York City was almost twice as strict as the emission standard set for Philadelphia and Chicago. (We attach a copy of the Department's notices proposing and establishing these emission standards. The quotations are from them.)

We support the Revision of Abatement Proceedings Amendment (Admt. No. 154, Sec. 8). The Clean Air Act presently provides that before an injunction action against interstate polluters is begun by the federal government there must first be a statutory conference followed by a hearing, with an opportunity after each for the states and the alleged polluters to take action. This amendment would eliminate the conference step. We think experience has shown that the statutory conference serves no purpose which is not better served by the hearing.

We support the Advisory Committee Amendment (Amdt. No. 181, Sec. 9). We note its provision for an air quality advisory committee of the Federal Department heads whose responsibilities may be affected. We note also its provision for industry advisory committees. And we note that these committees are to be consulted on proposed criteria under Sec. 103 and on proposed standards. We think all this will strengthen the criteria and the standards and will strengthen the Clean Air Act.

Very truly yours,

H. K. INTEMANN.

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

[42 CFR Part 76]

PREVENTION, CONTROL AND ABATEMENT OF AIR POLLUTION FROM FEDERAL GOVERNMENT ACTIVITIES; PERFORMANCE STANDARDS AND TECHNIQUES OF MEASUREMENT

NOTICE OF PROPOSED SULFUR OXIDES EMISSION LIMITS AND CONTROL MEASURES

In accordance with the provisions of § 76.5(c), notice is hereby given that the Secretary of Health, Education, and Welfare intends to adopt the limits on the emission of sulfur oxides and the control measures set out in the following revision of § 76.5(c), 30 days after the publication of this notice. The limitations and control measures will be effective October 1, 1968, and will be applicable as indicated to Federal facilities located in the New York and Chicago Standard Consolidated Areas and in Philadelphia Standard Metropolitan Statistical Area, as defined by the Bureau of the Budget.

These limitations and control measures are intended to assure that emissions of sulfur oxides from Federal facilities in the designated areas are minimized to the extent practicable, as required by section 4(c) of Executive Order 11282, May 26, 1966.

The limits to be established take cognizance of the varying severity of the sulfur oxide problem in the designated areas, which requires more restrictive measures in the New York Standard Consolidated Area than in the other areas. Such limits and the related measures will be subject to review and revision in the light of changing circumstances and technology.

It is also proposed to correct the number of the Bureau of Mines Circular referred to in § 76.1(c).

Interested persons are invited to submit written comments, suggestions or objections (in duplicate) regarding the proposed revisions to the Secretary of Health, Education, and Welfare, Washington, D.C. 20201, within 20 days after publication of this notice in the FEDERAL REGISTER. Federal, State, and local officials and affected parties who desire consultation in addition to, or in lieu of, the submission of written comments, suggestions or objections, will be arranged upon written request filed with the Secretary not later than 7 days after publication of this notice in the FEDERAL REGISTER. Data and information supporting the proposed revisions are available upon request from the Division of Air Pollution, Public Health Service, DHEW, Washington, D.C. 20201.

Part 76 would be revised as follows:

1. Section 76.1(c) would be amended to read:

(c) "Ringelmann Scale" means the Ringelmann Scale as published in the U.S. Bureau of Mines Information Circular 7718.

2. Section 76.5(c) would be amended to read:

(c) (1) Combustion units of all Federal facilities or buildings located in the following areas shall comply with the applicable emission limitations and control measures set out below:

(i) In the New York Standard Consolidated Area, the emission rate of sulfur oxides (calculated as sulfur dioxide) from fuels used in combustion units shall not exceed a maximum emission rate of 0.35 pounds per million B.t.u. (gross value).

(ii) In the Chicago Standard Consolidated Area and in the Philadelphia Standard Metropolitan Statistical Area, the emission rate of sulfur oxides (calculated as sulfur dioxide) from fuels used in combustion units shall not exceed a maximum emission rate of 0.65 pounds per million B.t.u. (gross value).

(2) If compliance with the above emission standard is to be accomplished by means of controlled fuel quality, the agency responsible for each Federal facility in the designated areas shall establish appropriate fuel specifications to insure that the above emission limitations are met and shall provide for adequate tests to ascertain that delivered fuel meets the applicable specifications. If removal of sulfur oxides from flue gases is used to control emissions, the facility shall pro-

vide for continuous monitoring and recording of the sulfur oxide content of flue gases emitted. The sulfur content of fuels shall be determined in accordance with current recognized testing procedures of the American Society for Testing Materials. The sulfur content of the flue gases shall be determined in accordance with current recognized testing procedures of the American Society of Mechanical Engineers.

(3) The limitations and measures established in subparagraph (1) shall be revised or amended only after consultation with appropriate Federal, State, and local officials and affected parties. Not less than 30 days prior to prescribing such revised or amended limits or measures, the Secretary will publish in the FEDERAL REGISTER notice of his intention to adopt such limits or measures, and will thereafter publish in the FEDERAL REGISTER the limits or measures established. The Secretary may at any time designate other urban areas which suffer from extremely high air pollution levels, and after similar consultation, and publication in the FEDERAL REGISTER, prescribe such limits or measures as he determines are necessary to carry out the intent of Executive Order 11282.

(Sec. 5, E.O. 11282)

Dated: November 17, 1966.

JOHN W. GARDNER, *Secretary.*

[F.R. Doc. 66-12661; Filed, Nov. 21, 1966; 8:50 a.m.]

TITLE 42—PUBLIC HEALTH: CHAPTER I—PUBLIC HEALTH SERVICE, DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE (SUBCHAPTER F—QUARANTINE, INSPECTION AND LICENSING)

PART 76—PREVENTION, CONTROL, AND ABATEMENT OF AIR POLLUTION FROM FEDERAL GOVERNMENT ACTIVITIES: PERFORMANCE STANDARDS AND TECHNIQUES OF MEASUREMENT

RINGLEMANN SCALE AND SULFUR OXIDES EMISSION LIMITS AND CONTROL MEASURES

On November 22, 1966, notice of proposed rule making was published in the Federal Register (31 F.R. 14785) setting out the text of a proposed revision of this part which, among other things, would establish limits on the emissions of sulfur oxides and prescribe control measures for Federal facilities located in the New York and Chicago Standard Consolidated Areas and in the Philadelphia Standard Metropolitan Statistical Area. The period of public participation was thereafter extended to February 10, 1967, by notice published in the Federal Register on December 29, 1966 (31 F.R. 16628).

Due consideration has been given all relevant material presented by written comments and in consultations with a number of affected parties.

The air quality criterion upon which the emission limitations are based represents conclusion drawn from studies of the adverse health effects of sulfur oxides at various time-concentration levels, which support the finding that 24-hour average levels of sulfur dioxide should not exceed 0.1 part per million more than 1 percent of the time annually. Based on these studies, the necessary reductions and the maximum emissions were derived individually for each area.

This criterion of sulfur dioxide concentrations represents a desirable objective for communities with sulfur oxide pollution problems. It should be recognized, however, that the objective cannot be realized immediately by all combustion sources in every area under present technology and with available low sulfur fuel supplies. This emphasizes the need and urgency for acceleration of research into the removal of sulfur from fuels and stack gases and for the prompt application of knowledge as it accrues.

The limited number of Federal facilities, however, makes compliance with the emission limitations practicable by such facilities by October 1, 1968, a step which will assure that emissions of sulfur oxides from Federal facilities in the designated areas are minimized to the extent practicable, as required by section 4(c) of Executive Order 11282.

Accordingly, the revisions to Part 76, as set out below are hereby adopted effective on publication in the Federal Register.

Part 76 is revised as follows:

1. Section 76.1(c) is amended to read:

§ 76.1 Definitions.

* * * * * * *

(c) "Ringelmann Scale" means the Ringelmann Scale as published in the U.S. Bureau of Mines Information Circular 7718.

* * * * * * *

2. Section 76.5(c) is amended to read:

§ 76.5 Sulfur oxides.

* * * * * * *

(c) (1) Effective October 1, 1968, combustion units of all Federal facilities or buildings located in the following areas shall comply with the applicable emission limitations and control measures set out below:

(i) In the New York Standard Consolidated Area, the emission rate of sulfur oxides (calculated as sulfur dioxide) from fuels used in combustion units shall not exceed a maximum emission rate of 0.35 pounds per million B.t.u. (gross value) heat input.

(ii) In the Chicago Standard Consolidated Area and in the Philadelphia Standard Metropolitan Statistical Area; the emission rate of sulfur oxides (calculated as sulfur dioxide) from fuels used in combustion units shall not exceed a maximum emission rate of 0.65 pounds per million B.t.u. (gross value) heat input.

(2) If compliance with the above emission standard is to be accomplished by means of controlling fuel quality, the agency responsible for each Federal facility in the designated areas shall establish appropriate fuel specifications to insure that the above emission limitations are met and shall provide for adequate tests to ascertain that delivered fuel meets the applicable specifications. If removal of sulfur oxides from flue gases is used to control emissions, the facility shall provide for continuous monitoring and recording of the sulfur oxide content of flue gases emitted. The sulfur content of fuels shall be determined in accordance with current recognized testing procedures of the American Society for Testing and Materials. The sulfur content of the flue gases shall be determined in accordance with current recognized testing procedures of the American Society of Mechanical Engineers.

(3) The limitations and measures established in subparagraph (1) of this paragraph shall be revised or amended only after consultation with appropriate Federal, State, and local officials and affected parties. Not less than 30 days prior to prescribing such revised or amended limits or measures, the Secretary will publish in the FEDERAL REGISTER notice of his intention to adopt such limits or measures, and will thereafter publish in the FEDERAL REGISTER the limits or measures established. The Secretary may at any time designate other urban areas which suffer from extremely high air pollution levels, and after similar consultation, and publication in the FEDERAL REGISTER, prescribe such limits or measures as he determines are necessary to carry out the intent of Executive Order 11282.

* * * * * * *

Dated: March 17, 1967.

[SEAL] JOHN W. GARDNER, *Secretary.*

[F.R. Doc. 67-3206; Filed, Mar. 21, 1967; 12:59 p.m.]

Senator MUSKIE. Our last witness today is Mr. Leonard S. Wegman, partner of Leonard S. Wegman Co., representing Consulting Engineers Council of America.

Mr. Wegman, I am sorry I have to leave but Senator Spong has agreed to sit.

Senator SPONG (presiding). Mr. Wegman, you go right ahead.

STATEMENT OF LEONARD S. WEGMAN, PARTNER, LEONARD S. WEGMAN CO., REPRESENTING CONSULTING ENGINEERS COUNCIL OF AMERICA

Mr. WEGMAN. Thank you, Senator.

I greatly appreciate this opportunity to give my views to your committee relative to the Air Quality Act of 1967.

My name is Leonard S. Wegman. I am a partner of Leonard S. Wegman Co., a consulting engineering firm of New York City, and I am here today in behalf of the more than 1,800 firms which comprise the Consulting Engineers Council of the United States of America. Many of these firms, including my own, have been actively engaged for many years in the design, construction, inspection, and operation of both publicly and privately owned pollution abatement works.

The three major points we wish to make are:

(1) We heartily endorse the objectives of this act. It holds great promise for our national welfare.

(2) The act can be strengthened and made more effective.

(3) The private enterprise firms in Consulting Engineers Council have both the ready ability and the technical expertise to help public agencies and private organizations alike to meet the objectives of this act.

FEDERAL AIR QUALITY REPORTING SYSTEM

The Federal Air Quality Administration established by this act can accomplish much merely by gathering and coordinating air pollution responsibility and authority into one agency. Standards applicable to interstate air emission sources, to be adopted under this act, will be a useful plane of reference for State and local pollution-control units. However, the necessarily wide latitude given to the Secretary could result in establishing relatively weak standards, and vitiating the goals of this and related air quality acts. What is needed is a strong drive which the public can understand and support.

We, therefore, respectfully suggest that this act require the Secretary to investigate and report on a Federal air quality reporting system, using as a basis the existing Public Health Service national air sampling network. Our U.S. Weather Bureau has, from its inception, been regarded as essential to the Nation's welfare. If the interstate pollution of air is to be abated, and since the interstate movement of air requires tracking for the identification and reduction of pollution, the installation of an expanded Federal reporting network seems essential.

Such a network could sample suitable levels of air for pollutant content, indicate wind direction and intensity, and by comparison with upstream readings, a rough picture of what a given area is adding to or subtracting from the pollution load will be determined.

By analysis of airborne particulates obtained during sampling, especially in populous and inversion-prone areas, source identification may be assisted, leading directly to effective abatement.

Further, a ready comparison can be made on a monthly or other

periodic basis of how the several States are accomplishing improvements in air quality.

And lastly, advance indications of potentially hazardous weather inversions with air pollution significance may be forecast.

UNIFORMITY OF REPORTS

Section 109 and other sections authorize the Secretary to rely on reports of the character, kind, and quantity of pollutants discharged and the means used to reduce emissions of pollutants.

There is no uniform base or content of reports used in air pollution control activities. Thus, one locality may, by its report base and content, accept a pollution source which would not pass the scrutiny of another report form used by another locality.

It would help designers of air pollution control systems, as well as enforcement agencies, to use a standard basis and qualified personnel for measuring and classifying both pollutants and the devices and systems used for reducing pollution discharge.

TECHNOLOGICAL AND ECONOMIC FEASIBILITY FOR IMPROVING AIR QUALITY

Basic to achieving improvement in air quality is technological and economic feasibility. The Solid Waste Disposal Act, Public Law 89–272, wisely provides financial assistance to State and local governments for the conduct of disposal operations—to demonstrate such feasibility.

We respectfully recommend an enlargement and redirection of emphasis of this program.

There is critical need for comparative assessment of air pollution control results from day-to-day operations of a potential source of pollution rather than placing too great a reliance on laboratory or university scale operations and research.

This in turn requires that an industry or municipality be ready to experiment with untried devices or systems before adequate operational evaluation can be made.

Here we have an obstacle to consistent progress because the gamble, from the industry's or municipality's viewpoint, is much too hazardous. (May I insert, parenthetically, that Senator Randolph's amendment goes to this very point; that is, the need for providing assistance in moving ahead rapidly.) We believe this obstacle can be overcome if, rather than partial financial assistance, the Federal Government were to underwrite the entire installation and test operation of a promising system with the understanding that, if it works, an appropriate reimbursement will be made by the owner to the Government. The risk factor is removed from local shoulders and, in effect, the cost of possible failure is spread over the entire Nation on the valid basis that the entire Nation will benefit from each gain in air pollution control systems. An analogous precedent for such conditional loans is the successful operation over the past 18 years of the Federal Community Facilities Administration, which has made many hundreds of planning advances.

ROSLYN HARBOR INCINERATOR IN NORTH HEMPSTEAD, N.Y.

Without such underwriting of costs, only rarely will important advances be achieved, like that acomplished at the new Roslyn Harbor 600-ton refuse disposal plant for the town of North Hempstead in New York State. I cite North Hempstead because the Wisconsin Chemical & Testing Co., an independent testing agency, has determined that the air pollution reduction achieved by this plant exceeds by 70 percent that which is proposed by the New York State Air Pollution Control Board for plants constructed between 1962 and 1969, and that the plant's actual emission control is 20 percent better than the code slated to go into effect for plants built after 1969. The construction and operation of the pollution control system at Roslyn Harbor costs about $1.34 per person per year for the 175,000 people who are served by the plant.

Here was an exceptional case where municipal officials confronted by a serious problem (and a total lack of Federal assistance) resolutely determined they would shoulder the financial burden themselves. The result is an important advance which sets new goals and new standards in pollution control.

Unfortunately, few industries or municipalities can run the risk of similar forward steps. Company presidents or city mayors do not relish the prospect of defending themselves, if failure occurs, against the inevitable opposition barrage. Government underwriting can reduce this roadblock.

GRANTS FOR AIR POLLUTION INSTALLATION

Just as the Federal Government has assumed an increasing share of the cost of water pollution abatement installations, so should study begin promptly of a system of grants to support air pollution control installations. Air pollution is certainly far less a respecter of State boundaries than water pollution which generally follows prescribed stream routes.

When substantial air pollution is reduced the benefits are spread over many square miles. I believe that the Secretary should be authorized to investigate and report on the feasibility of a system of backup grants which would hasten and encourage industry and local government to proceed with air pollution reduction.

TECHNICAL RESOURCES IN CONSULTING ENGINEERS COUNCIL

Our Consulting Engineers Council represents more than 1,800 firms with 6,000 member principals and 25,000 staff engineers and related employees engaged in virtually every field of engineering practice. Most of the planning, design, inspection of construction and consultation on engineering projects in this country where engineers in private practice are engaged is handled by our member firms.

In compliance with CEC standards and membership requirements, our member firms have no commercial or financial interests which would prejudice their complete engineering independence and objectivity. We are almost all small businesses and must perform with con-

sistent competence and economy to retain the good reputations essential for maintaining positions of responsibility and authority.

Air quality improvement will require many man-hours of engineering. We believe that factors of demand and technical competence will necessitate reliance upon independent firms in private practice.

In this regard we heartily concur with the provisions of section 108 of the bill which authorizes the establishment of regional air quality commissions. Our only concern is that some direction is needed in the legislation to assure that the two residents to be added from each State are not also governmental employees. As it now stands it is possible that all the persons serving on such commissions be affiliated with a Federal agency or agencies and as such reflect only the Federal view. Many private citizens, certainly many qualified consulting engineers, could make valued contributions to the various regional commission discussions and deliberations.

Since we are judged largely by our accomplishments, we have a competitive spur not possessed by others. Staffing of the Federal Air Quality Administration should, therefore, take account of the air pollution abatement expertise available from the private sector.

Policy, direction, scheduling and overall management by the Government, coupled with detailed planning and execution by private enterprise, offer the most efficient partnership to achieve an urgently needed improvement in the quality of our Nation's air in the shortest possible time.

Thank you for this opportunity to express our views and recommendations.

Senator SPONG. Thank you very much. As you made your statement you made a brief comment about Dr. Middleton's testimony this morning with his colleagues about their uncertainty at this moment. Would you care to amplify upon that?

Mr. WEGMAN. My comment, Senator, related to the systems and devices for reducing air pollution. I do not comment on the hazards or health hazards of pollutants except to accept the fact that particulates particularly and certain gas discharges also are potentially hazardous. The thrust of my statement goes to accept the overall strategy, goes to tactics.

Senator SPONG. If I understand your statement, you are endorsing the legislation.

Mr. WEGMAN. That is correct, sir.

Senator SPONG. You are also suggesting that a reporting system be put into effect.

Mr. WEGMAN. Yes, sir.

Senator SPONG. You are suggesting that rather than partial grants you believe it would be advisable to choose certain industries and install antipollution equipment on the basis that if it were successful the users would have to pay for it.

Mr. WEGMAN. That is correct, sir.

Senator SPONG. You believe that the best start would be to select certain industries throughout the United States where it is determined

that there is a problem and provide the cost of installation of anti-pollution devices on an experimental basis.

Mr. WEGMAN. That is correct, sir; because then if the experimental installation works you have a day-to-day demonstration of its actual ability, of what it is doing. The uncertainty as to which direction to go or what systems to use is thereby greatly reduced, with the probability of more rapid advance.

Senator SPONG. You are also endorsing Senator Randolph's research proposal?

Mr. WEGMAN. Yes, sir; I think that goes right to it. I cited the Roslyn Harbor case because up until that installation there was no municipal incinerator anywhere in the country that came near the desired air pollution emission limitations. The town of North Hempstead did install an exceptional type of equipment and has achieved exceptional results. What we would like to see is a similar arrangement of new devices or new systems tried in several other communities, and also in industry, rather than wait until the slower natural sequence of events has someone come up, accidentally, with a further idea for improvement.

Senator SPONG. Now the other observation that you made was that as far as the regional commissions are concerned you want some provision in the legislation that would assure that the two resident members were not Government connected.

Mr. WEGMAN. That is correct, Senator; because we feel that, while the Government has a very definite responsibility to protect the public, at the same time the view from the non-Government side could accelerate achievement of the goal by providing, perhaps, a more realistic approach, rather than leaving the impulse and direction entirely up to the Federal side.

Senator SPONG. Mr. Wegman, this question does not go to your statement except to your endorsement of the need for additional Federal legislation at this time. Do you believe that the situation in the United States has reached a stage where we have to do something?

Mr. WEGMAN. Most certainly, sir. Most certainly. And we know that we can do it.

I have a little vial of fly ash here which has been trapped at the Roslyn Harbor incinerator. When you realize that most of the solid waste disposal plants in the United States are now putting this material out into the atmosphere at rates in the order of 20 to 30 pounds per ton of refuse burned and this fly ash emission can be radically reduced, well, why not reduce it? Why not move ahead?

I think we will only move ahead if we have effective, comparative systems. One locality can then measure its performance against another and, if found wanting, insist, at the local level, that these advances are made and that proper control equipment is installed. We know how, we know the technological feasibility. As I mentioned in my statement, at the Roslyn Harbor plant the cost was $1.34 per year per person. Although this relates only to reducing the air pollution from refuse disposal, I am sure that all of those people are very

happy with this achievement. What we should like to see is that this know-how and the spur to do it will be accelerated throughout the country.

Senator SPONG. Thank you very much, Mr. Wegman. Thank you for your patience in waiting all day to testify.

Mr. WEGMAN. Thank you, Senator.

Senator SPONG. The hearings will adjourn until 9:30 tomorrow morning.

(Whereupon, at 1:54 p.m., the subcommittee recessed, to reconvene at 9:30 a.m., Thursday, May 18, 1967.)

AIR POLLUTION—1967

THURSDAY, MAY 18, 1967

UNITED STATES SENATE,
SUBCOMMITTEE ON AIR AND WATER POLLUTION
OF THE COMMITTEE ON PUBLIC WORKS,
Washington, D.C.

The subcommittee met, pursuant to recess, at 9:35 a.m., in room 4200, Senate Office Building, Senator J. Caleb Boggs presiding.

Present: Senators Randolph, Spong, Cooper, Boggs, and Baker.

Also present: Richard B. Royce, staff director; Leon G. Billings, and Richard D. Grundy, professional staff members; and Richard E. Gerrish, minority staff director.

Senator BOGGS. The subcommittee will come to order.

Before we proceed, I would like to make this little statement on behalf of the committee.

Today we conclude scheduled hearings on S. 780, the President's Air Quality Act of 1967, and proposed amendments.

This week we have heard an excellent group of witnesses discuss the state of the art of air pollution control and recommend areas in which more research seems essential. I am sure that the witnesses scheduled today will provide the subcommittee with more of this type of important and needed information.

Our first witness is Mr. Bruce E. Kester of Missouri Portland Cement Co., representing the Cement Advisory Committee of the American Mining Congress.

Mr. Kester was especially cooperative in agreeing to stay over and testify today after the pressure of time did not allow his appearance yesterday.

We thank you very much, Mr. Kester, and if you would proceed we would be very grateful.

STATEMENT OF BRUCE E. KESTER, DIRECTOR OF RESEARCH, MISSOURI PORTLAND CEMENT CO., REPRESENTING CEMENT ADVISORY COMMITTEE, AMERICAN MINING CONGRESS, ACCOMPANIED BY JACK GILLILAND, DIRECTOR OF QUALITY CONTROL, IDEAL CEMENT CO.

Mr. KESTER. Thank you, Senator Boggs.

Senator BOGGS. Thank you, sir.

Mr. KESTER. May I introduce to you Mr. Jack Gilliland, who is director of quality control of Ideal Cement Co.

Senator BOGGS. Glad to have you, Mr. Gilliland.

Mr. KESTER. Senator Boggs has identified me.

I am Bruce Kester, director of research for Missouri Portland Cement Co. I am speaking on behalf of the Cement Advisory Committee of the American Mining Congress.

May I first thank you for this opportunity to present information to you on the "state of the art" of pollution control within our industry.

To set the stage for this discussion, a brief glance at some characteristics of our industry may be helpful.

Ours is a basic industry. While some of you may never have noticed, nor to your knowledge seen, a cement plant, each of us here today has shared in cement's end use product—concrete.

The Statue of Liberty, the Washington Monument, the Gateway Arch, and the Golden Gate Bridge all rest on concrete support. The sidewalks we used this morning, the foundations of this building, the acres of terrazzo flooring in Washington, D.C., the launch pads at Cape Kennedy, and the ornamental bird bath in your garden all share this basic commodity: cement.

The diversity of use is paralleled by an equally diverse manufacturing facility. Of the some 180 operating cement plants in the United States, no two are alike. The variables that nature exhibited in the vast mineral resources of this Nation are extended into the manufacturing process, and the infinite ingenuity of man further develops these differences.

With the exception of a few tiny experimental units, all portland cement produced in this country is made in rotary kilns, the largest piece of moving equipment in any industry, a cylindrical tube with the raw materials introduced into one end, and intense heat at the opposite end. Here the similarity ceases.

Beyond the inherent variation of the raw materials, production units range in size by a ratio of 20 to 1. Multitudinous auxiliary equipment added to the three basic process units—a raw material grinding mill, the rotary kiln, and the finished cement grinding mills—multiply the variation from plant to plant.

A typical modern cement plant costing $25 million could, if its total output were sold in the overglutted market, produce a product selling for less than 1 cent a pound in such volume that annual sales for that plant would be in the order of $10 million. This penny-a-pound product is in itself a dust rivaling in fineness milady's face powder selling at several dollars a pound.

My own personal experience covers in excess of 30 years' research in the pyroprocessing industries. Thirty-odd years ago, I was assigned a problem of improving the efficiency of a dust collection system on a line hydrator. Over 30 years ago, cement plants had installed electrostatic precipitators on the rotary kiln and, at that time, no Federal, State or local laws required such cleanliness.

I am proud to be a part of an industry which has continually sought to be a good neighbor, has sought to control its emissions and improve its process. These desires and attitudes are changed today only in that they are increasingly a part of management's concern in the overall problem of cement production. The cement industry has long maintained an active appraisal of the health aspects of its employees, and over the history of the industry, no evidence is known to exist that the cement plant emissions are harmful.

We have labeled this discussion as "state of the art." It will be apparent as we progress that it is an "art"; despite the electronic age of today with sensors, telemetry and computer capabilities, pollution control is far from an exact science. Progress is being made; the development of glass bag fabrics for high temperature dust capture and the automatic peak voltage control of electrostatic preciptators are developments of the very late 1950's to early 1960's. We continue these efforts not because of rule and regulation, but because in the long run it is the proper development of a responsible industry.

The pollution control sought in the cement plant is largely control of particulate or dust emission. It is apparent that with no two cement plants being alike, no two dust arrester systems can be alike. The lay person would assume if you wanted a dust collector for some unit in the process it would be simple to call an equipment supplier and ask for model 1967, install it, and satisfy the neighbors with your plant cleanliness. Unfortunately, this is impossible.

Not only must the cement producer have kuowledge of all available types and manufacturers of dust collecting equipment, but he must, to protect himself, enter into the basic design of the structure, and establish the operating conditions for the unit.

The producer of dust collecting equipment will not tell you how many cubic feet of gas a 16- by 500-foot rotary kiln will exhaust. He will not tell you how much dust must be removed from the volume of gas to satisfy the community, nor will he even, with any certainty, estimate how must dust will exit from the kiln and enter the collector.

The cement producer must provide the basic design criteria. If he has an inadequate staff, he is forced to engage the services of a consultant engineering firm. Let me interject that cement producers are not unique in this regard, all pyro-processing industries—steel, lime, phosphate, and others—share our position.

If the cement producer has been 100 percent right in his projections of gas volumes, temperatures, pressures, moisture content, size, and amount of particulate matter; if he has provided all the necessary means of reprocessing or disposing of the collected dust and the dust collector has been properly selected for all these conditions, then the emissions will be at a satisfactory low level.

Unfortunately, the story does not end here, nor happily. In the eternal battle of efficiency, cost, and, at times, market demand, the cement producer is bound to attempt improvements in his process.

I recall an instance where dust collecting equipment was installed on two rotary kilns with a capacity of 6,800 barrels per day and a guaranteed efficiency of 99.5 percent dust suppression. The march of progress developed the use of internal chain heat exchangers in the dry process kiln just 7 short years ago. Today, the same two kilns are producing 9,500 barrels per day and, as you can imagine, the formerly dust-free emissions are now not quite as dust free.

The 40-percent increase in production was matched or exceeded all down the line of design criteria, gas volume, gas temperature, pressure, velocity, the amount of dust to be collected and, yes, unfortunately, even the amount of dust escaping.

The operation and maintenance of dust collectors is a rather awesome chore. I have recently taken a tour of the 10 latest and reportedly best dust collector systems on the rotary kiln, some less than 60 days

old in operation. I feel it is significant that in all of the 10 plants there were workmen busy at repairs and replacements of parts, sealing of air leaks, insulating of hoppers, and other modifications.

Other than the basic kiln itself, no unit in the cement plant receives more attention and greater maintenance effort than the dust arresters. Continuing efforts progress toward heat and abrasion resistant metals, erosion and corrosion control, fabrics of greater strength and wear resistance, electrical component stability, and a host of other variables.

We do this and have done this prior to rule and regulation; the current air pollution publicity has merely increased our efforts.

Assuming our selection, installation, operation and maintenance of the dust collector are each advanced as far as the art of today allows for a particular plant, how do we know that the control will satisfy the local rules and regulations, the State air pollution laws, or some air quality criteria.

To test a cement plant for dust emission, the cement industry is referred to the American Society of Mechanical Engineers Power Test Code developed for powerplant emission from coal burning steam generation plants. This code is most commonly written into the rules and regulations of pollution control bills.

Recall again, if you will, the wide variety of cement plant configuration and attempt to visualize with me the complexity of such testing. And then consider that for every 10 pounds of coal ash (which is collected and discarded by the powerplant) there are 600 pounds of finely divided powder which are the raw materials of the cement, and consider also, that if at all chemically, physically, and economically practical, the collected dust must be returned to the process. You will now grasp somewhat the complexity of our problem.

To run a stack test on a cement plant is an involved procedure. Some cement companies are equipped to conduct these tests; others hire an engineering firm to conduct the tests for them. In either case, to determine compliance to a code regulation costs between $2,000 and $3,000 for each such test.

At the present time, the Research and Development Division of the Portland Cement Association has undertaken the task of refining this procedure from the rather simple case of a powerplant emission to the many times more complex case of the cement plant emission.

Beyond the stack testing for emission, many other problems, as yet unsolved, are with us. When air quality criteria are discussed, it becomes apparent that we do not have, but we urgently need, a procedure which will relate the dust particles in ambient air to the emission source.

When a cement plant is located in an isolated rural spot, it is possible to, with some degree of confidence, estimate that plant's contribution to the ambient air quality. When the plant is contiguous to industry concentration, how can you separate the cement plant's contributions from the steel mill, the coke oven, the powerplant, or other industry? Frankly, this problem causes much of our concern with air quality criteria.

The Public Health Service in the Missouri-Illinois Interstate Study devised the so-called alkalinity-acidity fallout test based on upwind and downwind sampling. Our attempts with this procedure have been

completely inconclusive. Hemeon Associates, an air pollution consultant firm, has developed a trace element fallout test which has some reliability, but is cumbersome, time-consuming, and variable with various atmospheric conditions. Here again, the Portland Cement Association laboratories are undertaking studies to relate air quality to cement plants.

When discussion turns to the more recently identified pollutants such as oxides of nitrogen and other fume pollutants, we are, in the cement industry, in an area of no knowledge. I cannot, nor do I, believe any cement producer can tell you if there are, or how much there are, of the oxides of nitrogen in our stack emissions.

Again, I can report to you that studies are under way, both in individual cement plants, and in our Portland Cement Association laboratories, not only to ascertain what pollutants may exist, but, further, if they are detected qualitatively, how to determine them quantitatively.

Perhaps it will not be out of place to close this serious discussion with a somewhat lighter note on a curious inconsistency of the air pollution problem.

It has been reported in learned scientific journals that carbon dioxide levels from burning of fossil fuels is increasing in our atmosphere, and that this increase is paralleled by an increase in atmospheric temperature to a potential melting of the ice caps and inundation of our coastal cities.

It has been equally scientifically reported that the dust level in our atmosphere is increasing, and, by shielding us from the sun's rays, is paralleled by a decrease in temperature to a predicted second ice age. Thus, it seems that the cement plant which burns large quantities of fossil fuel and emits dust to the atmosphere is the ideal device to maintain our ecological balance.

Gentlemen, I thank you for your attention.

Senator BOGGS. Thank you, Mr. Kester.

It is not as simple as it looks, is it?

Mr. KESTER. No, sir.

Senator BOGGS. I want to say that I have been encouraged by your testimony that the industry certainly has been working on this problem of air pollution.

When I heard you testify that you could put in a control apparatus that would give about 99 percent control, my spirits got real high there. Then you went on and indicated that with an increased production of that equipment, why, we would cut it down 40 percent.

Can't they keep that equipment up with the production load?

Mr. KESTER. Senator Boggs, it requires modification of the equipment to get back to the level. However, we in the cement industry have agreed to some rather stringent numbers.

For example, the State of Illinois, and there are four cement producers in the State of Illinois, and the Illinois board established a 99.7 percent dust collection efficiency or a tenth grain per standard cubic foot, whichever were the more stringent for a particular plant is the law in the State of Illinois. This was passed April 15, I believe. I know it is the law, anyway.

Senator BOGGS. You say you have about 180 plants operating?

Mr. KESTER. Yes.

Senator BOGGS. On the new facilities, the new plants now, would they not at the time of construction of the plant build in everything that technology knows about it? That has proven feasible, at least?

Mr. KESTER. Maybe I had better let Mr. Gilliland answer that because they have built five new plants and I have only built one.

Senator BOGGS. Mr. Gilliland.

Mr. GILLILAND. We have built in the last 15 years five new plants located in both urban and rural areas. All of those plants were equipped with the very latest control devices and only one of those locations actually had an existing law that we designed to build our collection equipment around.

Senator BOGGS. Did you have to get a permit to build a plant?

Mr. GILLILAND. No; we didn't have to get a permit to build it but in all cases we put on the most effective dust collecting equipment regardless of there being no law applied.

Senator BOGGS. What is the result you are getting with this new equipment?

Mr. GILLILAND. Excuse me?

Senator BOGGS. What kind of results are you getting with this new equipment?

Mr. GILLILAND. We are getting very excellent results.

Senator BOGGS. Is it satisfying the community that had the law?

Mr. GILLILAND. Yes; it is. That one, however, and the latest one in Seattle has only been in operation a couple of months and it has been very excellent. We see no reason why it should change.

Senator BOGGS. But judging from that experience with those five new plants, and even though your testimony shows that every plant is different and in a different situation, but the state of the art for cement plants is practically to the place now where you can accomplish effective air pollution control, dust control; isn't it?

Mr. GILLILAND. Yes; it is.

Our problem is not with our new plants. Our problem is with our older plants. It would be very costly to bring them up to date in their air pollution control.

Senator BOGGS. On the cost, would it be possible for you to submit for the record at least an illustrative situation to give us some idea of the order of magnitude of the numbers involved in improving the performance of older plants to meet the performance of newer ones?

Mr. GILLILAND. Yes; we can prepare that.

Senator BOGGS. You can comment on that now briefly if you want to, but submit for the record in particular.

(Subsequently, Mr. Kester submitted the following material:)

MISSOURI PORTLAND CEMENT CO.,
St. Louis, Mo., May 29, 1967.

Hon. E. S. MUSKIE,
Chairman, Senate Subcommittee on Air and Water Pollution, Senate Public Works Committee, New Senate Office Building, Washington, D.C.

DEAR SENATOR MUSKIE: Following my testimony on Senate Bill S. 780 Senator Boggs asked the question of Mr. Gilliland and me as follows: "On the cost, would it be possible for you to submit for the record at least an illustrative situation to give us some idea of the order of magnitude of the numbers involved in improving the performance of older plants to meet the performance of newer ones?"

As pointed out in my presentation, no two cement plants are ever alike and therefore we are not completely sure of the comparison basis. However, on a new

plant, the installation of a dust collector on the kiln to collect 99.7 percent of the dust at a 500,000 cubic foot per minute gas rate would, by our latest estimate, cost approximately $1,000,000 for the collector, the necessary auxilliaries of fans, breaching and dust handling equipment and allowing for installation and engineering costs. This $1,000,000 for a new plant can be compared to costs developed in prior work done for the Missouri Air Conservation Commission of $1,655,000 to obtain 99.6 percent efficiency or $4,765,000 to obtain 99.86 percent efficiency on rebuilding the St. Louis kiln dust collections. The prior work is attached as a copy of a letter to Mr. T. Harris, a P.H.S. employee on loan to the State of Missouri. The I.W.C.C. ad referred to in this letter is attached for reference.

I hope this information will be of some help in clarifying the differences.

Yours very truly,

BRUCE E. KESTER,
Director of Research.

ST. LOUIS, MO., *January 9, 1967.*

Mr. T. HARRIS,
Air Conservation Commission of the State of Missouri,
St. Louis, Mo.

DEAR MR. HARRIS: You have asked that I develop the basis for the I.W.C.C. ad statement on cement industry costs for meeting either the I.W.C.C. proposed code or the Interstate Study proposed code based on the process weight table. The relative requirements of these two proposals are (for the size of our St. Louis operation) either 0.1 grain per standard cubic foot of stack gas on the I.W.C.C. proposal or 0.03 grain per standard cubic foot of stack gas derived from the process weight table of the San Francisco Bay Area code and entered into the Interstate Study section on regulations.

As I told you verbally, the information developed is based entirely on extrapolations from known and existent dust collection installations of the pyroprocessing industries. To my personal knowledge no cement plant installation presently meets the I.W.C.C. proposal on a continuous basis for 24 hours a day, 7 days a week, month after month operation. We believe that the best available and extrapolated knowledge of dust collection may meet the 0.1 grain per standard cubic foot requirement of the I.W.C.C. proposal on a continuous basis. We do not believe that the process weight table requirements can be met by any conceived or extrapolated collection system on a continuous basis.

You will, I am sure, realize that costs of equipment developed in short periods of time without detailed engineering studies are merely educated guesses. These are not just guesses of Missouri Portland Cement Company personnel based on previous installations, but have been arrived at in brief consultations with the largest manufacturer of dust collection equipment and the best available consulting engineering service to the cement industry.

Neither the equipment manufacturers nor the consulting engineers will guarantee performance to meet the I.W.C.C. proposal of 0.1 grain per standard cubic foot without imposing arbitrary limits on operational procedures. These arbitrary limits required Missouri Portland Cement Company personnel to define precisely all operational variables of present and predicted operation practices which results in our basically guaranteeing knowledge of plant operation throughout its existent life and ourselves guaranteeing the collection equipment.

Since no one but our own engineering staffs could hope to estimate the operational control required to meet the 0.1 grain per standard cubic foot limit, neither the consultant engineer nor the equipment manufacturer will guarantee performance of any system to a 0.03 grain per standard cubic foot based on present knowledge either of their staffs nor can we so guarantee based on our present and predicted operational practices.

It should be apparent that to achieve a continuous 0.1 grain per standard cubic foot would require design to a much lesser effluent concentration. In this case the manufacturer of collection equipment has suggested a design value of 0.04 grain per standard cubic foot which would hopefully at all times meet the 0.1 grain requirement.

When the question of the proposed 0.03 grain per standard cubic foot regulation was discussed with consulting services again, it was apparent we could not design at 0.03 grain and hope to maintain the value on a continuous basis and while no such efficiencies have ever been attained, nor is it believed feasible to attain, design criteria has been based on a 0.01 grain effluent.

After this lengthy preamble I will set forth the costs developed on two condtions:

1. That the commission acknowledge that these are crude tentative cost estimates based on combined experiences of producer, supplier and consultant and not based on detailed engineering studies.

2. That the commission recognize that we as producers do not believe the process weight requirements can be met on a continuous basis despite compounding of equipment beyond technologically sound, economical and practical limits.

a. To meet the I.W.C.C. proposal of 0.1 grain per standard cubic foot. Design value 0.04 gr/scf.

Based on 5,000,000 barrel annual cement production at an operational 500,000 cfm kiln gas effluent at 25 grain per standard cubic foot inlet loading.

Cost per cubic foot equipment and installation $2.65. Engineering fees and contractors overhead and profit at 7.5% and 17.5% respectively = $0.66.

Total erected cost $3.31 per ft^3 or $1,655,000 for the St. Louis plant.

Erection time—minimum after all design and arrival of equipment—90 days. Since a normal 30 day overhaul period is allowed, 60 days or 18% of annual production is lost.

b. To meet the process weight table requirements of 0.03 grain per standard cubic foot. Design value 0.01 gr/scf. in our knowledge not considered attainable.

Based on 5,000,000 barrel annual cement production at an operational 500,000 cfm kiln gas effluent at 25 grain per standard cubic foot inlet loading.

Cost per cubic foot equipment and installation, $7.63. Engineering fees and contractors overhead and profit at 7.5% and 17.5% respectively, $1.90.

Total erected cost $9.53 per ft^3 or $4,765,000 for the St. Louis plant.

Erection time—minimum after all design and arrival of equipment—210 days. Since a normal 30 days overhaul period is allowed, 180 days or 55% of annual production is lost.

Ratio of cost of proposals

	Process wt.	IWCC	Ratio
Equipment only	$4,765,000	$1,655,000	2.9 to 1.
Lost production, percent of annual capacity	55	18	3.1 to 1.

I hope the above discussion of costs serves to adequately amplify the 3X cost statement of the I.W.C.C. advertisement. Additional discussion or enlargement of any facet will be provided on request.

Yours very truly,

BRUCE E. KESTER,
Director of Research.

A summary comparing the major clean air program proposals with interstate study proposals

Regulation	Clean air program	Interstate study	Comments
Iron and steel industry	Requires collection efficiency of 99.4 percent.	Requires collection efficiency of 99.7 percent.	The extra 0.3 percent would double the control equipment cost.
Cement plants	Requires collection efficiency of 99.6 percent.	Requires collection efficiency of 99.86 percent.	The extra 0.26 percent would triple the control equipment cost.
Catalytic crackers (petroleum refining)	Requires collection efficiency of 99 percent.	Requires collection efficiency of 99.5 percent.	The extra 0.5 percent would require a large expenditure.
Foundries	Will reduce present foundry cupola emissions by 83.2 percent.	Will reduce present foundry cupola emissions by 86.3 percent.	The extra 3.1 percent would triple the control equipment cost.
Other processes	Control by process weight code	Control by process weight code	No difference.
Emission of sulfur dioxide from use of fuel	Use lowest sulfur fuel available	Maximum sulfur limit of 2.25 percent	Fuel with maximum limit of 2.25 percent not available.
Emission of certain sulfur compounds	Requires conversion efficiency of 98 percent.	Requires conversion efficiency of 99.3 percent.	The conversion efficiency required by the interstate proposal is not being attained by any commercially operated plant in North America.
Emission of particulate matter from fuel burning equipment.	Requires collection efficiency of 97 percent for large sources.	Requires collection efficiency of 95.6 percent for large sources.	Clean air proposal meets ASME code which is more stringent.
Administrative provisions	Complete legal and administrative provision.	None	Clean air program is ready for adoption into ordinance form.

Mr. GILLILAND. Testimony was given last week by Mr. Wessels of our company that indicated that the air and water pollution devices—because they are associated together in disposing of the dust, we sometimes get into a water pollution problem—that it added roughly 20 percent to the cost.

Now, I don't have that in terms of modernizing old plants.

Mr. KESTER. Here I can help.

Senator BOGGS. Yes.

Mr. KESTER. In their plants which they just built, there was $4 million spent on dust collecting devices.

Now, the major dust collecting device is the one on the kiln, itself. In our plant, to collect dust at an equal efficiency on the kiln alone. the estimate is slightly in excess of $4 million to achieve it and this is taking out the old unit and putting in a new one.

So, you have increased the cost by, roughly, at least twofold in trying to modernize an old plant over an existing plant.

Senator BOGGS. Where there was a regulation on the books where you built one of the new plants, was it not more satisfactory in planning and building a plant to have a guide to shoot at, a regulation to shoot at? Didn't it give you a sense of better planning in that you were meeting the situation at a time when you could do it at the lowest cost and to meet a problem that has got to be faced sooner or later anyway?

Mr. GILLILAND. I doubt that the installation would have been much different because we were in downtown Seattle; we knew we had to have a very clean plant. It did mean that we had a definite number to look to in our plant.

Senator BOGGS. Senator Baker.

Senator BAKER. Mr. Chairman.

Let me ask this question. It is not specifically related, I suppose, to the burden of your testimony, but it is one that is basic to the concern of this committee, I believe, in the formulation of this legislation.

Would it, in your judgment, be economically more advantageous to your industry in the long run if there were a set of numbers or guidelines of reasonable low level for emission standards on the books to guide you in the construction of new plants for the future?

Might or might not this have a retroactive effect? Would it be useful in the orderly development and expansion of the cement industry if you had some sort of guideline on a national basis for what emission standards were and were not accepted?

Mr. KESTER. This is basically pointed to the fact that if there were a national standard, then the cost of dust collection in rural areas would be identical to the cost of collection——

Senator BAKER. Let me interrupt.

I didn't mean to imply that and that is an argument we frequently get into, that there would be the same level for emission standards in New York City as there was in a rural and remote area in West Virginia.

But, assume for the moment that the national standards were set at a very low level—that is, a not very strict level at the national level, but above that for problem areas such as urban areas, New York City and the like—would this not very stringent national level or standard be helpful in the orderly development and economical development of your plant for future years?

Mr. KESTER. I would think a not very stringent or even relatively stringent law would have almost nothing to do with the choice of location and direction of the cement plant. Basically, you locate them for raw material sources, manpower, electrical power, transportation facilities, and the market. These are the basic considerations.

Senator BAKER. But that does not determine whether you located in confines of a city or 20 miles outside the city?

Mr. KESTER. Yes; freight, 20 miles into the city would cost money.

So, if you can be in the city with the product, you save that extra cost.

Senator BAKER. So, you feel, as far as your industry is concerned, that under no circumstances should there be any sort of emission standard at all, stringent or otherwise?

Mr. KESTER. Oh, I think there should be local or area or even State standards; in fact, we face them in all of our plants.

We have three plants and they are, each of them, on an interstate line. They are on rivers. We believe firmly that there should be local ordinances and State and interstate compacts or air shed laws.

Senator BAKER. Does your company undertake some degree of pollution control regardless of location of the plant?

Mr. KESTER. Yes, sir.

Senator BAKER. Is this a matter of statute or regulation or moral conscience, or both?

Mr. KESTER. Well, I am happy to guess back at my predecessor's beliefs, but the electrostatic precipitators were installed in our St. Louis operation which is our original location long before my time in the early thirties.

Senator BAKER. Was it as a result of regulatory action by some governmental unit or because of the company's own initiative in response to some moral or conscious judgment that you ought to do it?

Mr. KESTER. It was the company's own initiative.

St. Louis is rather famous because of Mayor Tucker and his cleaning up the air and removal of smoke in 1940 and the removal of fly ash in 1948. The precipitators, as I say, were put into our plant in the early thirties.

Senator BAKER. The idea I am really trying to test is this: Might not, in the absence of some sort of not very stringent national emission standard, a company with the highly developed sense of public responsibility or corporate conscience be at a disadvantage competitively with another company in the absence of any regulation and might decide, well, we can pollute the surrounding countryside in the air envelope and gain 2 cents a barrel on our competitor.

Might not the absence of a national emission standard create an economic differential which would discriminate against those who want to do something?

Mr. KESTER. I would not think so myself, sir.

Senator BAKER. Well, why not?

Mr. KESTER. Because any cement plant put up today must have some emission control on it; that is, I don't think you could persuade workmen to work if you had no emission control.

Certainly, anybody who was not in the cement business within a very immediate area adjacent to your plant would be highly vocal and sue under the nuisance clauses and so forth.

So, we have to assume somewhere that you put some control on the plant yourself just because of your own workmen and because of the neighbors around you, be you considerate of them or just trying to protect yourself.

So, we get to the point that every plant has some degree of control right now and then we get to the fact that this does not then become the major or even a minor reason for selecting where I put my plant or where my markets are.

Frankly, I cannot answer for Ideal; I am not speaking for the Mining Congress now, but speaking for Missouri Portland Cement. We located our plants on the rivers for river water shipping and that is why they were there. Of course, we located each of them in essentially an urban area: St. Louis, Kansas City, and Paducah, Ky.

Senator BAKER. So, in summary, then, I take it your attitude and the attitude of the American Mining Congress is that there should be no national emission standards as such for the cement industry?

Mr. KESTER. That was the position taken last week by Mr. Wessels and is the position taken by the group of the Cement Advisory Committee, that there should not be national emission standards, that air quality criteria are the proper concern on a national level because air quality criteria is what we are breathing.

Senator BAKER. That is all.

Senator BOGGS. Thank you, Senator Baker.

Mr. Kester, how do you generally determine the availability of feasible control technology in building new plants?

Mr. KESTER. How do I determine the availability of new technology?

Senator BOGGS. Yes; the feasible technology of your new plants, whether the state of its art is effective.

Mr. KESTER. The cement industry is somewhat unique, Senator Boggs, in that we have perhaps the greatest interchange competitive companies, if you will, as to what we are doing.

Frankly, in the month of April I remarked that I had toured 10 cement plants, all with the newest and latest and best dust-collecting equipment, and this was for the purpose of designing the newest and best and most effective dust-collecting equipment in our St. Louis plant which is now 17 years old and does require by the Missouri statutes that we do something about this.

We look at what is done in the industry and then our engineering group and our technical groups decide what is wrong with what they put in in Seattle, for example; that they have a high maintenance problem in some portion of this and we think we can change this by improving the metallurgy. This is how we advance in the cement industry, interchange of information between member companies, and then hopefully our own expertise in material handling and the use of abrasion and temperature-resistant materials.

Mr. GILLILAND. I might mention, Senator, that we have in the Air Pollution Control Association a very active cement technical committee. As Mr. Kester has said, we have a very ready interchange of information between plants as to what they have developed and, of course, we are working closely with all the equipment manufacturers.

Senator BOGGS. I don't know of any further questions at this time.

I want to thank you both very much for your contribution this morning.

Mr. KESTER. Thank you very much, Senator Boggs and Senator Baker.

Senator BOGGS. Mr. Earl L. Wilson, president of Industrial Gas Cleaning Institute, and manager of the Industrial Gas Cleaning Department, Koppers Co., Inc.

Thank you, Mr. Wilson. We appreciate you being here.

Mr. WILSON. Thank you, Mr. Boggs.

Senator BOGGS. If you will, identify the gentlemen with you.

STATEMENT OF EARL L. WILSON, PRESIDENT, INDUSTRIAL GAS CLEANING INSTITUTE, AND MANAGER, INDUSTRIAL GAS CLEANING DEPARTMENT, KOPPERS CO., INC.; ACCOMPANIED BY CHARLES A. GALLAER, CHIEF ENGINEER, BUELL ENGINEERING CO., AND MEMBER OF THE ENGINEERING STANDARDS COMMITTEE OF THE INDUSTRIAL GAS CLEANING INSTITUTE; AND HERBERT R. HERINGTON, EXECUTIVE SECRETARY OF THE INDUSTRIAL GAS CLEANING INSTITUTE

Mr. WILSON. Mr. Chairman, I am president of the Industrial Gas Cleaning Institute, and also manager of Industrial Gas Cleaning Department of Koppers Co., Inc.

With me today is Mr. Charles Gallaer, chief engineer of the Buell Engineering Co., and a member of the Industrial Gas Cleaning Institute's Engineering Standards Committee.

Also with me is Mr. Herbert Herington, executive secretary of the Industrial Gas Cleaning Institute.

On behalf of the members of the institute, we thank you for the opportunity of being here today.

Senator BOGGS. We appreciate you being here.

Mr. WILSON. We commend you on your efforts to improve the quality of our air resource. We sincerely hope that in some measure we may contribute to the ultimate success of your endeavor.

First, I think you should know that we are a young organization, having been founded in 1960. Our members, though, are all companies who have for many years made and sold the equipment used to collect particulate matter, or, more correctly, aerosols. They have, in fact, an aggregate total of 635 years of experience, dating back to 1906, in designing, making and installing air pollution control devices.

As an institute, we have just begun to concern ourselves with the collection of gaseous pollutants even though many of our present members have been, and are now, working in this field.

It is a pleasure to announce that at our annual meeting held on May 4, 1967, the members of our institute voted to establish a gaseous emissions division, so we will be very concerned with gaseous control in the future. Plans are now being made to implement this action as quickly as possible.

In the field of particulate control, we estimate that our members account for approximately 75 percent of the dollar value of the equipment sold. This is based on independent estimates as well as on the survey on U.S. output of industrial gas cleaning equipment conducted in 1963 by the U.S. Department of Commerce.

It is in the field of particulate matter control that we believe we can be of greatest assistance to you since our members design, manufacture, and install each of the four types of devices used today. These are electrostatic precipitators, fabric collectors, mechanical collectors, and wet collectors.

The more common processes on which each of these is used may be found on attachment A which, with your permission, I will refrain from reading to conserve the valuable time of this commitee. If you wish, however, this and the other attachments to this statement may be included in the record.

Senator BOGGS. Without objection, they will be made a part of the record at the end of your prepared statement.

Mr. WILSON. Thank you.

Contrary to popular belief, ours is not a giant industry. To illustrate, the total value of orders for equipment received by the member companies of the I.G.C.I., not including cost of required auxiliaries or installation, averaged only $41.9 million per year over the last 7 years.

In 1965, our bookings amounted to just over $53 million; and 1966 bookings were just over $69.4 million.

A better picture of the aggregate size of the market can be obtained by including all required auxiliary equipment and installation costs, even though much of this work may be, and often is, done by others.

On this basis, the estimated total installed cost of the equipment supplied by members of the I.G.C.I. ran from near $72 million in 1961 to approximately $133 million in 1965, and on a delivered and erected basis would total nearly $175 million in 1966. This means that total expenditures in 1966 on industrial air pollution control equipment in the United States were about $235 million.

Much has been written on the state of the art of particulate control, and I stress the word "particulate." Since this information is readily available, I will confine my remarks to a few pertinent points.

Let us first answer the question, "What can be accomplished with today's equipment?" If we could forget economics and the normal attendant difficulties experienced in designing, installing, and using this equipment, and wouldn't it be nice if we could, particulate emissions could be virtually eliminated.

After all, our collectors can be designed and built to operate with efficiencies as high as 99.9 percent and they will collect all aerosols that are today regarded as pollutants.

Unfortunately, the practical limitations can't be overlooked. Such basic things as economics, space restrictions, disposal of collected material, normal wear and tear, incorrect sizing, changes in production capacity, inadequate maintenance and deterioration due to age do enter into the picture, precluding the attainment of such an ideal situation.

It should be pointed out that many companies have installed air pollution control devices to meet specific codes, and once installed the device cannot be made to perform at higher efficiencies. A reduction in allowable emissions, then, would require additional equipment or removal of the old and installation of a new and more efficient device. This is not only very expensive, but there are many cases where the room to do so just doesn't exist.

Another situation that could create a problem is that of sulfur limits

on the coal being fired in a boiler. The electrostatic precipitator, commonly used on this application, is sensitive to the amount of SO_2 in the gas stream. That is, a reduction in the quantity of this gas can, and often does, reduce the collection efficiency of a given precipitator. It is possible, therefore, that efforts to reduce the amount of SO_2 emitted to the atmosphere by restricting the amount of sulfur in the fuel may cause many installations to suddenly violate a code on particulate emissions where they were previously in compliance.

Since we can't, in actual practice, completely eliminate the emission of aerosols, what can we reasonably expect? Well, first, I think it is safe to say, that all present codes can be met through proper application and use of existing equipment.

We point out, however, that many existing codes use as a criteria of satisfactory operation, a stack plume of a density related to a reading on a Ringelmann chart or an equivalent opacity. This is really a subjective measurement based on individual interpretation of stack effluent appearance and, though handy to use, is no basis for design of cleaning equipment.

Ringelmann is only an indication of what is coming out but does not necessarily relate to the actual amount, by weight, of the emissions from the stack.

Stack appearance, and hence Ringelmann reading, is vastly affected by (1) particle size, (2) color of dust, (3) background, (4) light, (5) stack diameter, and (6) plume velocity, not to mention the vision and interpretation of the viewer. As a simple analogy, picture 1 pound of talcum and 1 pound of coarse gravel being thrown into the air quite some distance from you. In both cases it is 1 pound, but you would see only the talcum. The gravel would pass a Ringelmann test.

We can accurately size and design equipment to remove a specified percentage by weight of a known dust coming into the collector, but we can only estimate what the stock appearance will be. It is our belief, therefore, that it is unreasonable to use Ringelmann readings or equivalent opacity as a basis for design or as prima facie evidence of noncompliance with a code.

This, then, is an area where more research efforts could well be expended. There is a real need for a monitoring device, or technique, that will remotely and accurately measure stack effluents on a weight basis, or on some basis that will readily correlate opacity to measurement by weight.

In addition, there is still much to be done in developing economically attractive uses for the collected particulate. Open hearth dust, for example, is high in iron content but for the most part remains waste material. Tons of now unusable fly ash are collected daily.

These are just two of the many examples of waste materials that presently must be disposed of and which often constitute new air pollution problems during and after disposal. Few people appreciate the quantities involved.

Consider that an electrostatic precipitator installed on a new 1,000-megawatt power generating unit will collect 500 tons of fly ash per day. And the individual sources add up to incredibly large totals. The amount of fly ash alone collected in the United States annually would fill over 600,000 railroad hopper cars which would make a train almost 4,000 miles long.

The state of the art is such that research on particulate control devices can be, and is, primarily concerned with product improvement, cost reduction and development of new and different methods for doing the job.

We have recently conducted a survey of our member companies to determine the extent and kind of our involvement in research and development activities. We found that in the period 1960 to 1966 we increased by 71.5 percent the number of people on our payrolls who are engaged in research and development work.

In addition, the 16 companies that reported have budgeted a total of $2,968,900 for R. & D. work in 1967 with plans to spend 34.1 percent on improvement of existing equipment; 36.5 percent to develop new equipment; and 29.4 percent on research in new areas. Incidentally, about 9.2 percent of the total will be spent on developing new ways to collect SO_2. A copy of the summary labeled attachment B is appended to this statement.

Now, I feel sure that to many the expenditure of just $3 million seems very little. I point out, however, that it represents approximately 4.3 percent of our net sales of hardware, which were $69,417,-115 for 1966.

Before leaving the subject of research and development, I would like to say that the members of our institute were, and still are, in complete agreement with Dr. Arthur M. Bueche, vice president, Research and Development Center, of General Electric Co., when he said before the Subcommittee on Science, Research, and Development, U.S. House of Representatives, at hearings on "The Adequacy of Technology for Pollution Abatement," that the various classifications of research could be consolidated into two categories:

(1) Research that will produce information useful for establishing standards, determining necessary regulations, enacting appropriate laws and suggesting methods; and

(2) Research that will produce information useful in developing hardware for systems that can be manufactured and sold; and that through Government, university, and industrial laboratories can all contribute in both of these areas, it is logical that the bulk of the responsibility for the first category be that of the Government while the second category is largely the responsibility of industry.

He further said that * * * this job of cleaning air and purifying water will be completed most rapidly if attacked on a competitive basis, seeking the most economic solutions and offering a profit-incentive to those who learn how to do the job best." We heartily endorse this statement.

Regarding economic feasibility, it is the experience of the members of the institute that the four types of collectors have efficiency ranges over which they are generally considered economically acceptable. These are as follows:

	Percent
Electrostatic precipitator	80–95.5
Fabric collector	95–99.9
Mechanical collector	70–95.0
Wet collector	90–99.0

It should be borne in mind that each of these devices can be, and often are, designed and applied with operating efficiencies above as well as below the indicated range.

There is, then, a great deal of overlap which allows the prospective user some latitude in his selection. This is fortunate, indeed, since there are many considerations in selecting control equipment other than collecting efficiency.

Some of the more obvious of these are things such as particle size (a mechanical collector is inefficient on very small particles), a lack of water or potential water pollution problem with effluents (which would make a wet scrubber an unattractive choice), very high gas stream temperature (which could eliminate a fabric filter), or explosive gas stream (which would rule out an electrostatic precipitator).

To give a complete, or even accurate, picture of the economics of applying and operating dust collectors is impossible for many reasons, some of which have already been mentioned. We can, though, give you some rule-of-thumb costs for typical collectors of standard mild steel construction. These are as follows:

Type of collector	Dollars per cubic feet per minute equipment cost	Dollars per cubic feet per minute erection cost	Dollars per cubic feet per minute yearly maintenance and repair cost
Mechanical collector	0.07–0.25	0.03–0.12	0.005–0.02
Electrostatic precipitator	.25–1.00	.12– .50	.01 – .025
Fabric filter	.35–1.25	.25– .50	.02 – .08
Wet scrubber	.10– .40	.04– .16	.02 – .05

We attempted to define a range of operating costs to be included in this tabulation but due to the wide variation in figures available and some apparent discrepancies, we felt that it would be meaningless to do so.

The problem in getting usable information of this kind is confounded by such things as correctly determining the incremental operating costs of auxiliaries, which are due solely to the dust collector. A fan, for example, would be used even without a collector, so one cannot assume the entire cost of operating the fan is due to the air pollution control installation.

It is further confounded by considerable differences in maintenance procedures (some have preventive maintenance programs, while others do not), labor rates, power costs, et cetera.

In addition to the general cost information just mentioned, we offer some typical examples with the word of caution that the figures are, of necessity, approximations and do not represent either maximum or minimum costs.

Mr. Chairman, with your permission, I would refrain from reading these eight cases but would request that they be included in the record.

Senator BOGGS. They will be included in the record at this point.

(The material referred to is as follows:)

CASE NO. 1

Application of multiple tube dry centrifugal collector followed by a wet collector on a 200 ton/hour asphalt plant to meet most existing codes (.2 gr./cu ft. residual):

Medium pressure drop system

	Gas fired	Oil fired
Delivered and installed cost	$39,000	$49,500.
Operating cost	$3 per hour	$3 per hour.
Life expectancy	10 to 15 years	10 to 15 years.

High pressure drop system to meet future codes (less than 0.2 gr. per cubic foot residual)

	Gas fired	Oil fired
Delivered and installed cost	$47,500	$57,500.
Operating cost	$5 per hour	$5 per hour.
Life expectancy	10 to 15 years	10 to 15 years.

The 20+% added cost of oil fired over gas fired is due to the material of construction required to resist corrosion in the case of oil firing. I point this out simply to show that it is possible to have wide variations in cost for any specific type of application, even when they appear to be similar.

CASE NO. 2

Application of a medium to low pressure drop wet collector to a flue fed apartment house incinerator.

Volume: 1000–2500 cfm.
Temperature: at incinerator 600°–1000°F.
at roof level 180°–200°F.
Installed Cost: $3,000.00 to $4,500.00.
Horse Power Requirement: 1.5 HP.
Operating Cost: $.04/hr.
Maintenance Cost: $700/year/unit.
Life Expectancy: 15 to 20 years.

Here, too, the installed cost, though little compared to large industrial applications, varies widely.

CASE NO. 3

Application of a 98% efficient electrostatic precipitator to an industrial boiler of 150,000 lbs. steam/hr. capacity:

Precipitator equipment only approximately $40,000.00
Delivered and installed cost (including suporting steel, access facilities, ductwork, dust handling equipment, heat insulation): TOTAL $100,000.00.

In this example we used a multiplier of 2.5 to convert collector cost to a delivered and installed cost including required ancillary equipment. This multiplier was worked out by the members of the I.G.C.I. so that we might have a satisfactory method of arriving at approximate total costs. Figure 1 attached to this statement shows approximate costs for a range of sizes of fly ash precipitators and Figure 2 shows the effect of coal burned on the cost of the equipment.

CASE NO. 4

Application of a 99% efficient precipitator to a modern utility generating unit of 500 MW capacity (approximately equivalent to a boiler rating of 3,600,000 lbs. of steam/hr.):

Cost:

$535,000.00 for equipment only, or
$1,070,000.00 completely erected, including supporting steel, access facilities, and heat insulation.

Here you will note the multiplier used is 2 as compared with 2.5 in the preceding case. This is based, in part, on the fact that the much larger installation will usually have a lower ratio of erection and ancillary cost to collector cost. In addition, the previous example included some ductwork while this one does not.

CASE NO. 5

Application of a mechanical collector precleaner and glass bag filter to a dry process cement kiln of 7,500 barrels/day capacity to achieve 99+% collection efficiency. Delivered and erected cost, including supports and dust handling: Approximately $375,000.00.

CASE NO. 6

Application of a 99% efficient electrostatic precipitator to a large steel making basic oxygen furnace installation with a vessel capacity of 200 tons. Precipitator equipment only delivered and erected: $850,000.00.

CASE NO. 7

Application of cyclone collectors to the effluent of a cement clinker cooler. Collection efficiency=95%, air volume handled=50,000cfm, cost of collector=$18,-500.00, including erection and structural steel.

CASE NO. 8

Application of orlon cloth fabric filter collector to the effluent from a 30 ton/hour 15 ft. diameter electric furnace (12,500 KVA transformer). Collection efficiency 99%, handling ventilation air volume of 62,000 cfm catching 35# dust per ton of metal melted. Installed cost of collector: $73,000.00.

Mr. WILSON. Additional cases could be given, but I question the value of doing so. I have, though, included cost information on small cupola cleaning as shown on figure 3.

Because of the multitude of applications involved and the many diverse things that influence the cost of this kind of equipment, the most we can hope to do is give you a very general idea of the economics involved.

The subject of economic feasibility wouldn't be complete without a look at cost trends. Figure 4 attached, showing the approximate cost/CFM by efficiency for electrostatic precipitators used to collect fly ash clearly shows the drop in cost that has taken place in recent years. The other equipment types made by I.G.C.I. members have also experienced reductions.

Though it is impossible to say what the exact percentage drop was for the industry as a whole, we know that today equipment with high collection efficiencies can be purchased for the same amount of money as would have been required for much less efficient equipment 10 years ago. We are proud of this accomplishment, made, incidentally, while most everything else was going up in price.

I would like to turn now to some general comments on S. 780. Though it is not our province to determine what actually constitutes acceptably clean air, we do feel, on the basis of our experience, that it is impractical to expect an equal degree of air cleanliness throughout the country.

Furthermore, we believe each area, or region, that suffers from air pollution has its own peculiar set of problems. Because of this, we would encourage a regional concept rather than fixed countrywide emission standards.

It is true, of course, that for any region to get or maintain air that is acceptably clean there must be emission standards. The question may well be: Will universal standards give us better—or worse—air?

If emission standards are written so as to not unfairly penalize some in certain areas, they may not be stringent enough in others. In fact, it could even provide a means for many to lower existing requirements and thus increase the level of pollution.

It seems logical to first define the minimum ambient air quality that is acceptable—then analyze in detail what is required to attain or maintain this in each area or region—then set regional emission standards for all who contribute to the problem and not just selected sources.

We take strong exception to the provision which would authorize the Secretary to review and approve "facilities or devices or designs * * *." This is contrary to the basic precepts of free enterprise and could stifle the competitive process.

The manufacturer who designs, builds, and constantly works with the equipment is best qualified to judge whether it can perform as required. It is the province of Government to establish requirements and judge the results—not to determine or specify the means by which the results will be obtained.

In summary—

(1) We, in the gas cleaning equipment manufacturing industry recognize that there is, in fact, an air pollution problem in the United States that has become critical in many areas.

(2) We recognize that the solution must come from cooperative efforts of Federal, State, and local governments and industry.

(3) We recognize our obligation to aid in the solution of this problem.

(4) We believe our industry has the necessary skills and facilities to develop equipment to meet any now unsolved problems once they are defined as problems and covered by ordinances.

(5) We firmly believe in the fact that such problems will be satisfactorily solved in the fastest possible manner if done on a competitive basis.

(6) We strongly believe that control ordinances should be passed only after thorough study to insure that action is taken only on "real" pollution and not on "imaginary" pollution.

(7) We believe more in incentives than penalties to obtain compliance with air pollution regulations and feel that unjust burdens on specific people or companies should be avoided, if at all possible, commensurate with good air quality.

(8) We strongly urge that additional research be undertaken to develop a better method for the accurate quantitative measurement of air pollutants at the source.

(9) We believe there should be increased efforts to develop either uses for, or economical means of, disposing of the rapidly increasing quantities of waste materials being collected.

That is the end of my prepared statement.

I would like to now make one comment before stopping.

Relative to the figures that we have attached to this, it is not perhaps clear but it is possible to determine by looking at these to determine the added cost of a piece of equipment, specifically electrostatic precipitators, for going up in efficiency; that is, how much more would a 99 percent efficient unit cost than a 98 percent unit.

Thank you, Senator.

Senator BOGGS. Thank you.

Thank you very much, Mr. Wilson.

The attachments and figures at the end of your statement, to which you referred, will be placed in the record at this point.

(The material is as follows:)

ATTACHMENT "A"

USE OF PARTICULATE COLLECTORS BY INDUSTRY

Industrial Classification	Process	EP	MC	FF	WS	Other
Utilities & Industrial Power Plants	Coal	⊕	⊕	-	-	-
	Oil	⊕	⊕	-	-	-
	Natural Gas	—NOT REQUIRED—				
	Lignite	⊕	⊕	-	-	-
	Wood & Bark	+	⊕	-	+	-
	Bagasse	-	⊕	-	-	-
	Fluid Coke	⊕	+	-	-	+
Pulp & Paper	Kraft	⊕	-	-	⊕	-
	Soda	⊕	-	-	⊕	-
	Lime Kiln	-	-	-	⊕	-
	Chemical	-	-	-	⊕	-
	Dissolver Tank Vents	-	⊕	-	-	+
Rock Products	Cement	⊕	⊕	⊕	+	-
	Phosphate	⊕	⊕	⊕	⊕	-
	Gypsum	⊕	⊕	⊕	⊕	-
	Alumina	⊕	⊕	⊕	+	-
	Lime	⊕	⊕	+	-	-
	Bauxite	⊕	⊕	-	-	-
	Magnesium Oxide	+	+	-	-	-
Steel	Blast Furnace	⊕	-	-	⊕	+
	Open Hearth	⊕	-	-	+	+
	Basic Oxygen Furnace	⊕	-	-	⊕	-
	Electric Furnace	+	-	⊕	⊕	-
	Sintering	⊕	⊕	-	-	-
	Coke Ovens	⊕	-	-	-	+
	Ore Roasters	⊕	⊕	-	+	-
	Cupola	+	-	+	⊕	-
	Pyrites Roaster	⊕	⊕	-	⊕	-
	Taconite	+	⊕	-	-	-
	Hot Scarfing	⊕	-	-	+	-
Mining & Metallurgical	Zinc Roaster	⊕	⊕	-	-	-
	Zinc Smelter	⊕	-	-	-	-
	Copper Roaster	⊕	⊕	-	-	-
	Copper Reverb.	⊕	-	-	-	-
	Copper Converter	⊕	-	-	-	-
	Lead Furnace	-	-	⊕	⊕	-
	Aluminum	⊕	-	-	⊕	+
	Elemental Phos.	⊕	-	-	-	-
	Ilmenite	⊕	⊕	-	-	-
	Titanium Dioxide	+	-	⊕	-	-
	Molybdenum	+	-	-	-	-
	Sulfuric Acid	⊕	-	-	⊕	⊕
	Phosphoric Acid	-	-	-	⊕	⊕
	Nitric Acid	-	-	-	⊕	⊕
	Ore Beneficiation	+	+	+	+	+

KEY:

⊕ = Most Common
+ = Also Used
EP = Electrostatic Precipitator
MC = Mechanical Collector
FF = Fabric Filter
WS = Wet Scrubber
Other =
Packed Towers
Mist Pads
Slag Filter
Centrifugal Exhausters
Flame Incineration
Settling Chamber

Industrial Classification	Process	EP	MC	FF	WS	Other
Miscellaneous	Refinery Catalyst	⊕	⊕	-	-	-
	Coal Drying	-	⊕	-	-	-
	Coal Mill Vents	-	+	⊕	-	-
	Municipal Incinerators	+	⊕	-	⊕	+
	Carbon Black	+	+	+	-	-
	Apartment Incinerators	-	-	-	⊕	-
	Spray Drying	-	⊕	⊕	+	-
	Machining Operation	-	⊕	⊕	+	+
	Hot Coating	-	-	-	⊕	⊕
	Precious Metal	⊕	-	⊕	-	-
	Feed & Flour Milling	-	⊕	⊕	-	-
	Lumber Mills	-	⊕	-	-	-
	Wood Working	-	⊕	⊕	-	-

ATTACHMENT "B"

SUMMARY OF I.G.C.I. RESEARCH AND DEVELOPMENT INFORMATION SURVEY

(Answers Based on Reports Submitted by 16 of 17 Member Companies)

A. How much did your company spend on Gas Cleaning Equipment Research and Development in:

1965 $ 2,070,200
1966 $ 2,387,700

How much do you plan to spend in 1967? $ 2,968,900

B. The amounts included in the above figures for basic Research are:

1965 $ 440,000
1966 $ 490,700
1967 $ 551,500

C. List below the % of your R & D budget spent on the following: ($ based on 1967)

1. Improvement of existing equipment		34.1 %	$ 1,011,650
2. Develop new equipment		36.5 %	$ 1,083,250
3. Research in new areas			
a. SO_2 Collection	* 9.2 %		
b. Other _____	* 20.3 %	29.4 %	$ 874,000

* % of Total 1967 Budgets

D. Do you follow Academic research? Yes 13 No 3

If Yes, How? Publications - Societies - Seminars - Fellowships - Bibliography searches - Consulting arrangements - University contracts - Literature reviews - Technical meetings - News Releases - Patent searches

E. Availability of Technical People

1. Number of people ENGAGED IN R & D

	Yr.	#	Yr.	#	% Increase 1960 - 1966
a. Engineers	1960	63	1966	113	79.4 %
b. Technicians	1960	53	1966	83	57.6 %
c. Draftsmen	1960	42	1966	75	78.6 %
Total (a,b,c)	1960	158	1966	271	71.5 %

2. Are additional people readily available?

Yes 7 No 6 No Answer 3

F. What % of additional business can you handle with your current technical staff (do not consider production facilities)? Ave. 50 %

G. Can you obtain more technical people (engineers & draftsmen) to design and produce more equipment if required? Yes 14 No 2

H. What is the maximum anticipated increase in production as % of present production that you could reasonably handle?

Ave. 70+ % per year increase
Low 10 % High 200 %

NOTE: Questions G & H pertain to ability to increase production of equipment and not to research and development work.

Attachment "C"

MECHANICAL COLLECTORS

Efficiency vs. Particle Size
and
Approximate Cost Information

Prepared by the
Industrial Gas Cleaning Institute, Inc.
Mechanical Collector Division

Mechanical Collectors with broad range of equipment available will not meet all code requirements, therefore, efficiencies identified herein will cover the general range of efficiency expected on various applications.

1. Fly Ash (Power)

	Particle Size	Efficiency Range
a) Spreader Stoker fired boilers	20% -10 microns	90-95%
b) PC fired boilers	42% -10 microns	75-90%
c) Cyclone fired boilers	65% -10 microns	55-65%

2. Non-metallic Minerals (Mechanical Collectors used as primary stage where collector catch a part of process).

	Particle Size	Efficiency Range
a) Cement (kilns & process)	40% -10 microns	70-80%
b) Asphalt plant (Bit.mix)	10% -10 microns	80-95%
c) Lite Weight aggregate (kiln)	30-40% -10 microns	80-90%
d) Refractory Clays (kiln)	40-50% -10 microns	70-80%
e) Lime (kiln)	40-50% -10 microns	75-80%
f) Fertilizer plant (Process equipment)	40% -10 microns	80-85%

3. Steel (Ore benificiation)

	Particle Size	Efficiency Range
a) Pelletizing (Vertical shaft & rotary kiln)	10-40% -10 microns	80-95%
b) Foundry (general)	10-40% -10 microns	80-95%

ATTACHMENT "C"

	Particle Size	Efficiency Range
4. Chemical Process (Drying, Calcining)	10-40% -10 microns	80-95%
5. Incinerators (Municipal)	20-40% -10 microns	65-75%
6. Coal Processing (Thermal Drying)	10% -10 microns	90-97%
7. Petroleum (Cat Cracking Process)	18% -10 microns	99%+
8. General Industrial Application (In Plant)	10-60% -10 microns	65-95%

Cost of equipment F.O.B. unerected

a) Fly Ash (Power)	$.07 to $.14/cfm
b) Process (kiln) mild steel unlined	$.18 to $.25/cfm
c) Process (kiln, etc.) hi-temp. alloyed steel or refractory lined	$.65 to $1.30/cfm
d) General industry (in plant)	$.30 to $.40/cfm

General Costs by Application

Power

Equipment installed (excludes supporting structures, ductwork and heat insulation).

$300/MW of installed capacity
$50/MW/yr. operating cost

Typical Operating Costs

1.5 to 5 cents/cfm of gas handled/year.

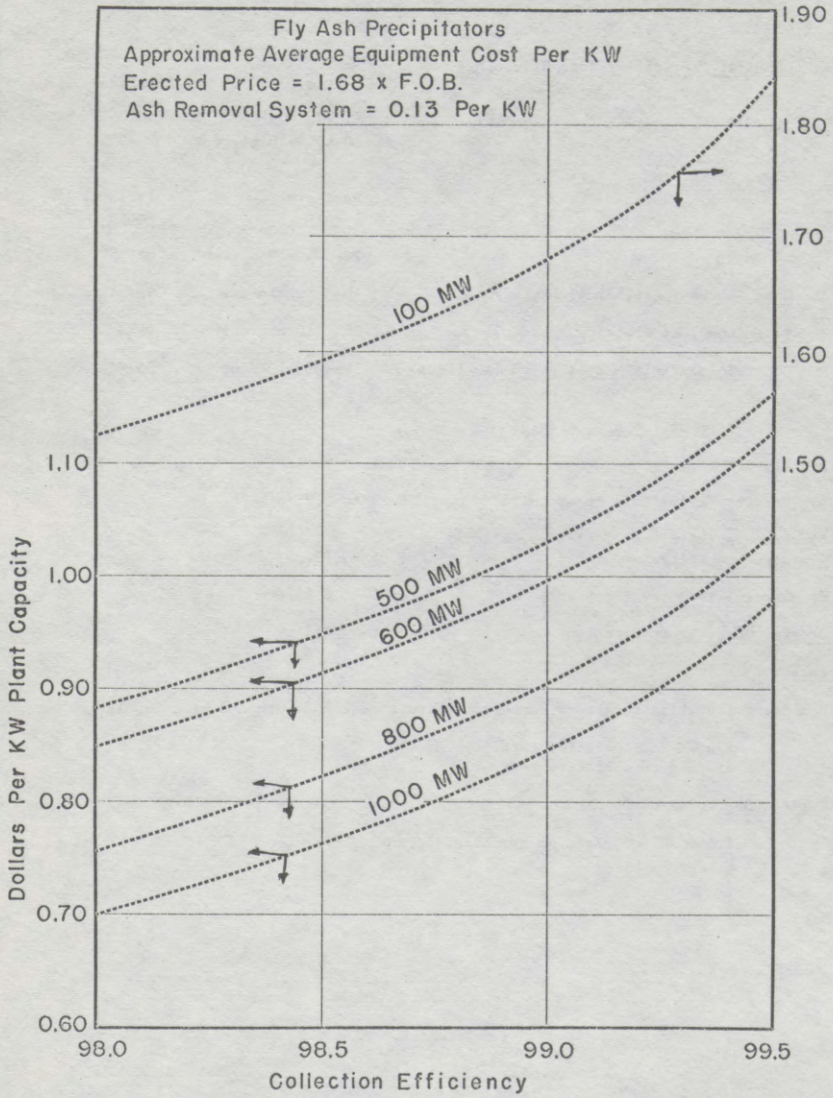
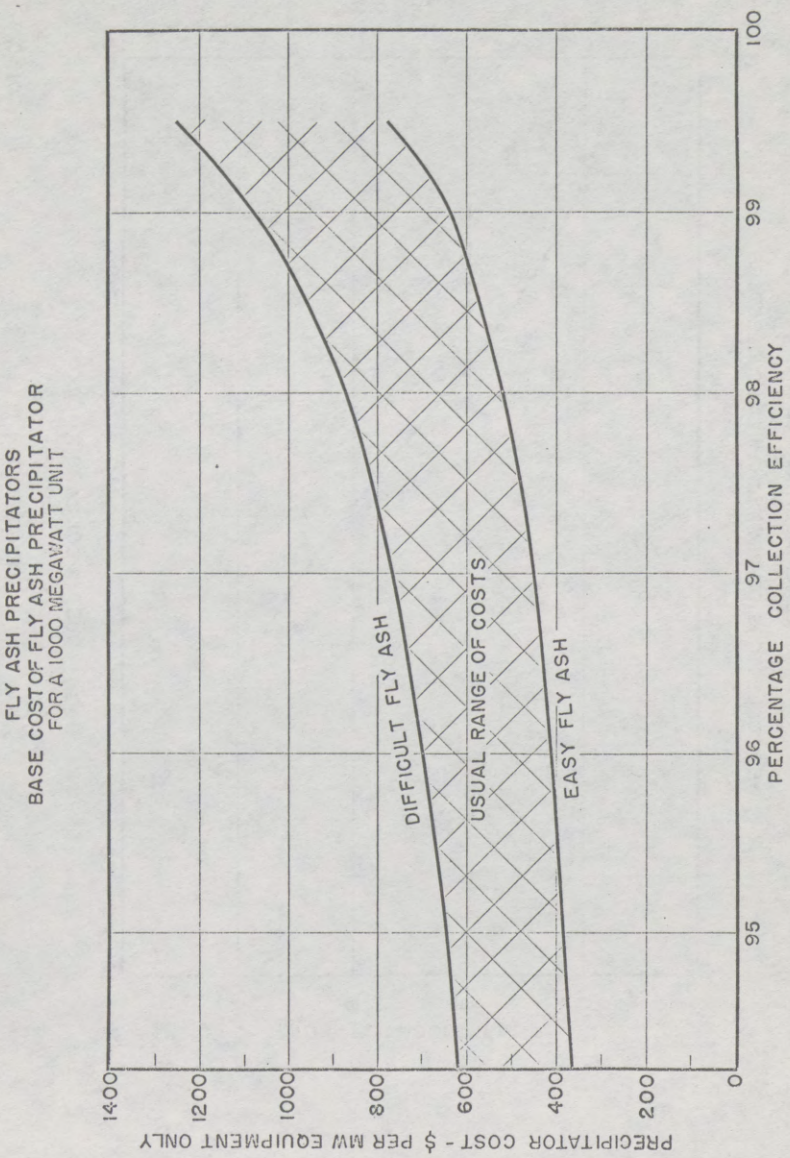
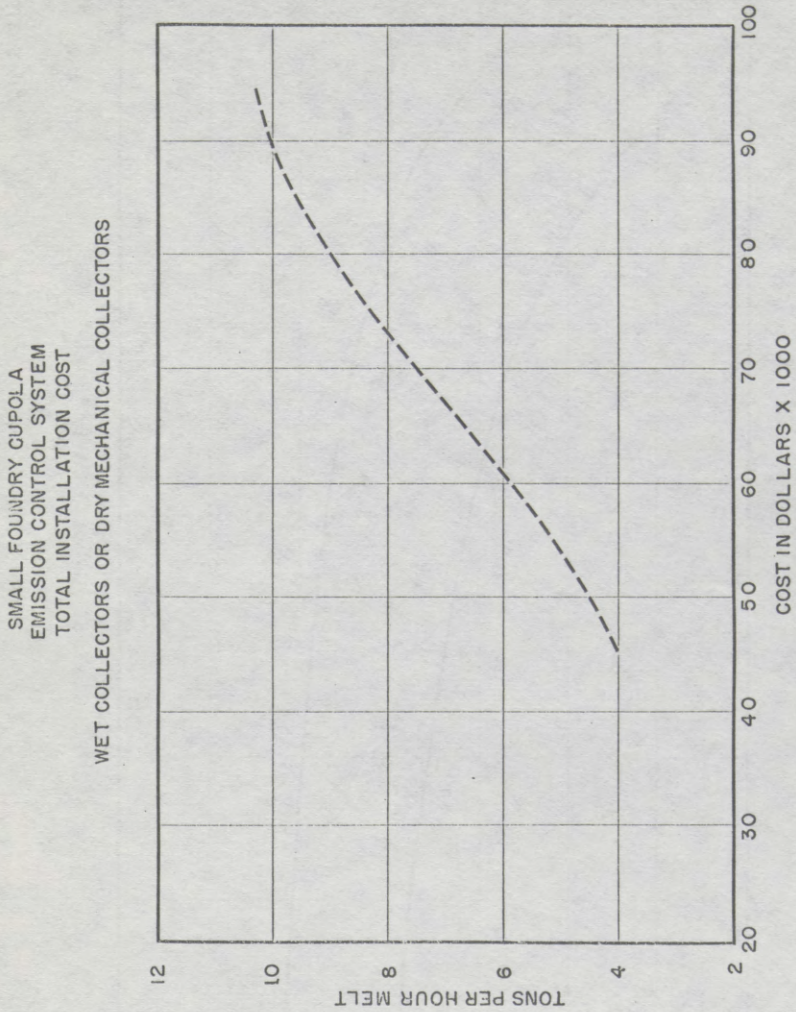


Figure 1 IGCI-5/67



IGCI - 5/67

FIGURE 2



IGCI-5/67

FIGURE 3

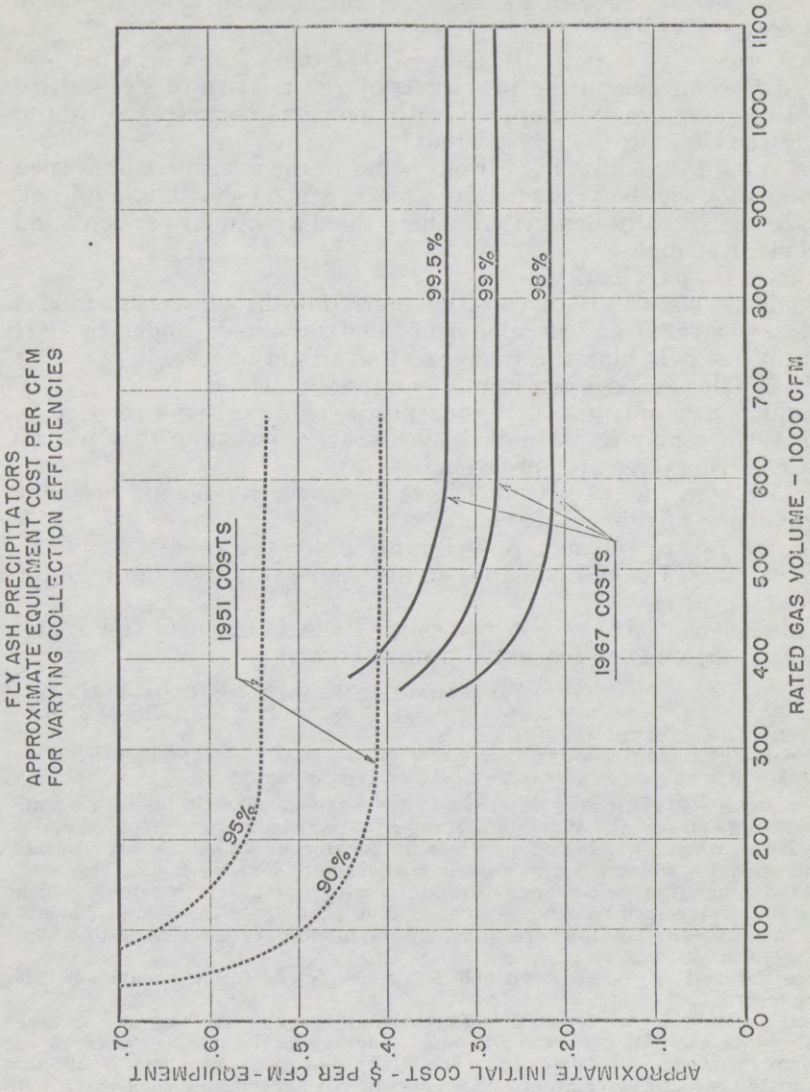


FIGURE 4

IGCI-5/67

Senator BOGGS. Mr. Wilson; in your testimony, you state:

It seems logical to first define the minimum ambient air quality that is acceptable—then analyze in detail what is required to attain or maintain this in each area or region—then set regional emission standards for all who contribute to the problem and not just selected sources.

That was in your part discussing 780. I don't know whether you wanted to comment on the provisions of 780 relative to Federal regional commissions as compared with compacts between the States. Would you have any thoughts on that?

Mr. WILSON. I think, sir, that our belief in the institute is that such a commission can be very effective and do a good job; it should not, though, be federally dominated. There should be equal participation of all involved in it.

Senator BOGGS. Thank you.

Would the institute be in a position in itself or through member firms to utilize research and development funds available under S. 780?

Mr. WILSON. I think the answer to that would be "Yes."

Senator BOGGS. Yes; you would be interested. Good.

Could you supply us with your position or positions relative to patents which may result under such research, assuming they participate in a Federal research program?

Mr. WILSON. That, sir, I don't have an answer to. We did not have an opportunity to discuss that at all.

Senator BOGGS. If you care to, supply it for the record.

Mr. WILSON. I would be happy to determine this and supply it for the record; yes, sir.

(Subsequently Mr. Wilson transmitted the following letter in response to the foregoing request for information:)

INDUSTRIAL GAS CLEANING INSTITUTE, INC.,
Rye, N.Y., May 25, 1967.

Hon. EDMUND S. MUSKIE,
Chairman, Subcommittee on Air and Water Pollution, U.S. Senate, Committee on Public Works, New Senate Office Building, Washington, D.C.

DEAR SENATOR MUSKIE: On May 18 I had the privilege of testifying before your Subcommittee on Air and Water Pollution. After concluding my prepared statement, I was asked a number of questions by Senator Boggs and Senator Baker. One question, for which I had no answer, was asked by Senator Boggs. This was, "Could you supply us with your position or positions relative to patents which may result under such research, assuming they participate in Federal funds?" I was then asked if I would care to supply the answer for the record, to which I replied in the affirmative.

Since the hearing, I have been able to determine the following and offer it for the record.

"Our Institute favors legislation which would provide for issuance of any patent rights accruing out of work done under Federally funded research to the company or companies doing the work. Absence of such a provision would not necessarily prevent any or all of our members from undertaking such work, but doing so would most assuredly provide great inducement for any company to utilize technical personnel and facilities in such programs."

Very truly yours,

EARL L. WILSON,
President.

Senator BOGGS. As you may have noted, it has been suggested elsewhere that apartment houses be required to install particulate control in such locations as New York City and other such areas.

Could you give us an idea of the ability of your member firms to meet this market and the time factors involved in such act, for example, in the city of New York?

Mr. WILSON. I think your later statement is the pertinent one. We have the ability to meet such a market demand but there is definitely a time element.

We could not, for example, start shipping overnight collectors for all the apartment houses in the New York metropolitan area. There is generally a 6- to 10-week minimum delivery requirement on equipment, so right to start with you have that.

In addition, relative to production capacity, if the demands were to do it all at one time, we could not; but if it were scheduled over a period of time, we definitely could.

Senator BOGGS. How would we dispose of the tremendous amount of fly ash, for example, without causing another pollution problem in water or land? Have you visualized that problem?

Mr. WILSON. We have talked a great deal about it but, quite honestly, we have been working at collecting it rather than getting rid of it. The pile is getting so significant, though, that if someone else doesn't do it, perhaps our members will become interested in this.

Senator BOGGS. Are you doing much research in odor control?

Mr. WILSON. I would have to say I don't believe so. I don't know specifically how much is done by each member company but there has been very little talk of it.

Senator BOGGS. Senator Baker.

Senator BAKER. I take it from your statement in general that it is your position that there should be some sort of regionally flexible emission standards.

Mr. WILSON. Would you repeat that, Senator, please?

Senator BAKER. I understand from your statement your position to be that you favor emission standards on a flexible regional basis.

Mr. WILSON. Not necessarily Federal standards; no, sir. I didn't say in here that they should be Federal standards. I simply said that standards would be required.

You can't attain a particular level of ambient air quality without having emission standards. I do, as does the institute, feel that there will have to be standards to accomplish this.

Senator BAKER. That is the point about which there has been some conflict in our hearings from time to time, whether or not, as a matter of fact, as a matter of practice, you could rely entirely on ambient air quality criteria, whether or not in order to obtain ambient air quality, you have got to be supplemented with emission standards of some type, whether Federal or local.

Your position is that you have got to have standards in order to do it?

Mr. WILSON. That is correct; yes.

Senator BAKER. There is one other feature that I would like to inquire about.

You state it seems logical first to define minimum ambient air quality that is acceptable; then analyze in detail what is required to attain or maintain this in each area. Well, I agree.

I suppose you have implied what I am about to ask, but it seems to me that one matter has not been emphasized in our various hearings and in the testimony of the several witnesses, and that is trying to identify the sources of pollution which in turn make up the quality of ambient air.

Don't you agree that we need to add a third step there, that of specifically and thoroughly identifying the sources of pollution?

Mr. WILSON. That is correct. This would be part of the analysis, very definitely. You would have to identify the sources of pollutants.

I believe in Los Angeles, for example, the first step to correct the smog problem was the backyard incinerators and they stopped that and nothing happened, and they tried several steps before they got to the automobile.

Senator BAKER. How much of a technical problem would it be to set up techniques to identify the principal contributors to the ambient air?

Mr. WILSON. Well, it is hard to define, really, because if you take an area such as metropolitan New York City where the pollutants are so massed together, to me in this case it would be an awfully difficult task to identify the source.

Senator BAKER. Isn't is necessary to identify the source before you can have any reasonable expectation of success in improving the air quality?

Mr. WILSON. Yes.

Senator BAKER. What are some of the techniques you could use to identify sources?

Mr. WILSON. Pardon?

Senator BAKER. What are some of the techniques that might be used to identify pollutant sources?

Mr. WILSON. By and large, the pollutant, itself, I think would be identifiable as coming from a particular source.

Iron oxide, for example, certainly would in all probability come from a steel mill complex; cement dust would come from a cement mill; fly ash from some coal burning installation.

Senator BAKER. The principal constituent would locate the source?

Mr. WILSON. Yes.

Senator BAKER. It would also be possible, as a matter of fact, would it not, to use radioactive tracers if you needed to separate similar elements or similar compounds in the atmosphere as to source and location? That would not be an unduly expensive process, would it?

Mr. WILSON. I don't have any idea of the cost of that process. I just don't feel qualified to answer. Perhaps Mr. Gallaer can answer that.

Do you have any thoughts on it?

Mr. GALLAER. My only thought on that, Senator, is that frankly I don't know. However, it may very possibly be by the AEC regulations because I don't know how much radioactive material would have to be put into a process to be able to trace the air pollution from it.

Senator BAKER. A very small amount.

Mr. Chairman, we can pursue this at another time, I suppose, but I would like to conclude with this one question to see if you agree.

Unless we do establish reliable techniques for trying to analyze and catalog the elements which make up the pollution in the atmosphere, before we attempt massive measures to cleanse the atmosphere we may run the very real risk that we will require an enormous amount of money for a program that won't produce the required results.

Mr. WILSON. You are 100 percent correct as far as we are concerned. This is a very real possibility. This may seem strange coming from the people who make the equipment, required if such a massive measure were taken, but we don't believe that this is necessarily the responsible way to do it, to just say let us go ahead and clean this all up.

We would much prefer a more rational approach to this: Identify what is the problem, first, and then and only then determine what is required to clean it up. As we pointed out in our testimony, when this is done our industry stands ready to supply the equipment to do the job.

Senator BAKER. I think you have done a remarkable job.

I might turn my thinking around the other way and put it this way: We simply can't afford in this field to indulge some sort of magic wish by establishing ambient air-quality criteria, but rather we have got to find out why we have polluted air and what polluted it before we are going to solve the problem.

Mr. WILSON. That is correct.

Senator BOGGS. Thank you, Senator Baker.

Thank you, Mr. Wilson, and gentlemen.

We appreciate your contribution.

Mr. WILSON. Thank you.

Senator BOGGS. Mr. Gambs, assistant to the vice president for chemicals, Consolidation Coal Co., speaking on fly ash utilization.

Mr. Gambs, glad to have you.

STATEMENT OF GERARD C. GAMBS, ASSISTANT TO VICE PRESIDENT, CHEMICALS, CONSOLIDATION COAL CO., ACCOMPANIED BY ERNEST W. ANDERSON, ADVERTISING MANAGER

Mr. GAMBS. Thank you.

I have with me, Mr. Ernest W. Anderson who is the advertising manager of our sales department. He is responsible for the ads which we have been running on fly ash.

If it is all right with you, I would like to read the summary statement which I have prepared.

We have a number of additional items, including my paper on the marketing of fly ash in the United States and Europe reprinted.

Senator BOGGS. That will be made a part of the record.

Mr. GAMBS. Thank you.

Fly ash is a major industrial mineral in the United States. On an annual tonnage basis, fly ash ranks as the sixth largest mineral produced in the United States today.

The only minerals which are greater in tonnage are sand and gravel, iron ore, limestone, and cement, so fly ash is beginning to rank as a

major mineral and on the basis of total tonnage is about 20 million tons a year at the present time.

Coal-burning power stations in the United States were among the first in the world to install efficient ash-collecting systems ahead of their stacks.

This whole program of ash removal from stack gases has been pursued by the power companies just about as fast as technological developments permitted and the progress in removing particulate matter has been phenomenal.

Each year since the first mechanical and electrostatic precipitators were installed, more efficient ones have come on the market and a modern power station today spends many millions of dollars on the ash collectors which can now remove over 99 percent of the particulate matter coming to their stacks.

As a result of the installation of these greatly improved collectors, and the growth of coal-burning power generation, the United States is now one of the world's largest producers of fly ash with an annual production of 20 million tons.

Until recent years, no attempts were made to utilize fly ash commercially and it was all dumped as a waste product. I estimate that for the first time in history more than 2 million tons of fly ash will be consumed for useful purposes in the United States in 1967. I feel confident in predicting that when all the present programs for using fly ash commercially are brought to fruition, fly ash shortages could possibly develop in many coal-burning areas of the country.

During 1966, I made two separate trips abroad visiting the United Kingdom, West Europe, and Russia, for the specific purpose of learning what was being done in these countries to utilize their fly ash constructively.

I learned that Russia is the only country in the world that produces more fly ash than the United States, 30 million tons a year, and has done virtually nothing toward consuming it usefully. I did find that the Russians are extremely interested in utilizing their fly ash, particularly in concrete because Russia produces even more cement than the United States and has a constant cement shortage. They cannot produce enough to meet the demands.

As a result of my talks with officials in Moscow, several Russians have visited in the United States and traveled across the country to learn what is being done here to utilize fly ash commercially.

West Germany produces a total of 9 million tons of fly ash a year. I learned there that most power stations burning bituminous coal reinject the fly ash into the boilers and convert it into a comparatively coarse granular slag. This slag is all used for aggregate and amounts to 4 million tons a year.

Germany happens to be a country short of good aggregates so this solution to a significant part of their fly ash problem fits nicely into their economy. Four million tons a year of fly ash produced from burning brown-coal, or lignite, is not used commercially there although I have reason to believe that it could be used in concrete with good results.

The Germans have also expressed interest in new uses for fly ash and I would expect that they will soon begin to use their excess fly ash in concrete and in other uses.

In France, the fly ash production is about 4 million tons a year and half of it, or 2 million tons, is sold commercially. The principal use for fly ash in France is in the manufacture of cement, either as a part of the raw material feed for the kiln, or interground and blended with cement clinker to make the equivalent of our portland-pozzolan cements.

The United Kingdom produces about 9 million tons of fly ash annually. Of this, about 3.5 million tons are utilized commercially. The largest single use in England is as a structural fill for land, in roadways, airport runways, road construction, and similar applications. Surprisingly, very little fly ash in England is used in concrete, but the English are very much interested in the progress of our fly ash concrete work in the United States and have, since my trip, visited several of our installations where fly ash was being added to concrete. I wish to repeat what I said earlier, that, based upon my own experiences here in the United States and what I have learned abroad, I am now confident that when all the various constructive uses of fly ashes are fully developed in the United States, we can consume it all and can thus make a substantial contribution to the betterment of society generally.

However, I wish to emphasize that no one single use, such as in concrete, for example, can accomplish this and some entirely new uses now under development will, no doubt, be needed.

One very important project on fly ash utilization is being sponsored by the Department of the Interior's Office of Coal Research at the Coal Research Station of West Virginia University. A good-sized pilot plant has been built and is just about to start producing high-grade bricks and blocks from a raw material containing 97 percent coal ashes consisting mostly of fly ash which is mixed with some bottom slag ashes.

The coal ash bricks and blocks made experimentally so far on smaller equipment appear to have superior qualities. If this project proves to be a commercial success, and I personally believe it will be, this use of fly ash alone could consume a lot of the U.S. fly ash. I cite this as only one example to bring to your attention the extent of the work going on in the United States to solve this problem.

Some of the reasons why industry is working so hard to utilize all fly ash commercially instead of disposing of it as a waste material can be summarized from the economic side, as follows:

(1) Utilization of fly ash will result in the reduction of the cost of coal burned by utilities and in turn ultimately means lower electric costs to the millions of consumers. The electric utility cannot only eliminate their disposal costs but receive income from the sale of fly ash. The combined total can mean as much as 1 to 2 cents per million British thermal units reduction in the cost of coal burned, and this is a substantial reduction.

From our coal industry side, this means that these credits rather

than debits to the utility will be most helpful in keeping our coal industry competitive with the nuclear power industry.

(2) As the country becomes more urbanized and the generation of electricity continues to grow, the areas available for satisfactory and economic fly ash disposal become more and more difficult to locate. Thus, it is recognized that the conversion of fly ash into commercially usable products is absolutely essential if the coal-burning power generating industry is to continue to grow at present rates.

With regard to the specific use of fly ash in concrete in the United States, there are no technical limitations when using a fly ash which meets the ASTM specifications. One of the principal jobs that needs to be done now is to make every engineer, architect, and contractor in the United States aware of the usefulness of fly ash in concrete. We are meeting with considerable success along these lines with the "ads" Consolidation Coal Co. has been running, copies of which have been furnished the committee members in the exhibits.

However, as mentioned above, we cannot solve the whole fly ash problem by putting it into concrete, although concrete uses could consume several million tons a year.

Additional and continued financial assistance by the U.S. Government for funding research projects on fly ash utilization would be very helpful in accelerating the commercial use of fly ash and I have previously mentioned one such worthwhile project. This, incidentally, is a splendid example of how government and industry can work together to bring about sound solutions to the problems of our highly industrialized society.

I should mention in closing that the National Coal Association is working with the electric utility industry with the objective of setting up a National Fly Ash Association. Such an association is badly needed in order to provide proper dissemination of all the information about fly ash uses across the entire United States, to provide the technical services needed, and to actively promote new and different uses just as fast as they are developed.

Thank you, Senator.

Senator BOGGS. Thank you, Mr. Gambs.

Can you give us an indication of the utilization of fly ash with regard to the economic transport of fly ash to areas outside the immediate urban community in which it is produced?

Mr. GAMBS. Yes. I could give you examples of how fly ash is transported, for example. It can be transported 100 to 200 miles and still be competitive with cement. Most cement plants figure they can transport 100 miles or something like that. Fly ash is transported about the same rate as far as the trucker's rate is concerned so that you can transport it really literally to almost any part of the country with the exception of the Far West where, of course, you have very few coal-burning situations.

Within the Eastern United States, you can get fly ash supplied to almost any place in the country and be economical.

Senator BOGGS. Well, your testimony holds out great hope in meeting this fly ash problem.

Mr. GAMBS. I am certainly convinced we will be able to solve it if we can get enough people aware of what its uses are and have enough work done on it to show what can be done.

Senator BOGGS. Is there available information on the mineral content of fly ash which could form a basis for research studies on resource recovery processes?

Mr. GAMBS. Yes. You are thinking probably of alumina to make aluminum.

Senator BOGGS. Yes.

Mr. GAMBS. Yes; we have looked at this very specific problem in our work with some of the aluminum people on it. Generally, the alumina content runs 25 to 30 percent of the fly ash. All of these data are available on the various minerals throughout the country.

Senator BOGGS. Thank you very much.

Senator Baker.

Senator BAKER. I don't believe I have any questions, Mr. Chairman.

I would like to commend this witness for his presentation and for pointing out how there can be a cooperative effort between government and industry in this area to reach a beneficial result.

Mr. GAMBS. Thank you very much, Senator.

Senator BOGGS. Thank you.

I might also compliment your company on the series of advertisements which are attached to your statement.

Your paper entitled, "Marketing Fly Ash—United States and European Programs," will appear in the record at this point. However, the pictures will not be reproduced with the article.

(The article is as follows:)

MARKETING FLY ASH—U.S. AND EUROPEAN PROGRAMS

(By Gerald C. Gambs, Assistant to Vice President—Chemicals, Consolidation Coal Co., Pittsburgh, Pa.)

(By 1980 U.S. fly-ash production will be 40 to 50 million tons, compared to 20 million now. Solving the disposal problem necessitates a sharp increase in utilization. Practice and planning abroad point to some of the ways.)

Fly ash, as coal men well know, is the fine powder resulting from the burning of coal after pulverization. It has presented the electric-utility industry with a disposal problem for a number of years. The problem is increasing because production of fly ash has been doubling every 10 yr, and satisfactory disposal sites have become more difficult to find. U.S. output is now about 20 million tons per year. In Europe, including the Soviet Union, it is about 50 million tons.

But by 1980 the U.S. will have 40 to 50 million tons of fly ash to dispose of, and today is not too soon to start seeking ways and means. Since it was known that England and Europe were well ahead of the U.S. in the commercial utilization of fly ash, and since an International Conference on Fly Ash was being held in Paris May 23–28, 1966, it was felt that there was a good opportunity to profit from a trip to several of the European countries to check on practice and developments. The trip lasted from May 13 to June 26. In addition to the writer, who visited Great Britain, France, West Germany and the U.S.S.R., the party included the following:

John Dragos, fuel engineer, Consolidation Coal Co. (Great Britain and France).

Dr. L. John Minnick, vice president and director of research, G. W. H. Corson Co. (Great Britain, France, West Germany).

Joseph F. Artuso, in charge, Cement & Concrete Sec., Pittsburgh Testing Laboratory (France).

Phillip W. Gutmann, manager, Special Products Development, Medusa Portland Cement Co. (Great Britain, France, West Germany, U.S.S.R.).

TASK FOR THE UNITED STATES

The production of fly ash has been increasing in all the countries visited. Current and future output and current utilization, in millions of tons, are summarized in the following table:

	Production		Utilization	
	1965	1975	1965	Percent of production
Great Britain	9	20	3.5	40
France	4	5	2.0	50
West Germany	10	15	2.7	27
U.S.S.R	20	40	[1] 1.5	3
United States	20	40	1.3	6
Total	63	120	10.0	

[1] Estimated.

The figures make it clear that much work has to be done on utilization if the U.S. fly ash problem is to be solved. Fortunately, the countries of Europe—principally Great Britain, France and West Germany—have made a great deal of progress in the commercial utilization of fly ash. They have developed large-tonnage markets, and it is believed that these same applications can be successfully exploited in the U.S.

From the tonnage standpoint, the most-important fly ash use to date is as a structural fill. Great Britain has developed this application to the point where it used over 1.3 million tons in 1965, which will increase to over 2 million in 1966. In view of the possiblities, this outlet should be thoroughly explored and the U.S. should get into the market as soon as possible. Millions of tons of fly ash could be disposed of in the construction of our highway systems and air fields, for example.

A second very-important market is the use of fly ash either in the manufacture of a portland-pozzolan cement or directly in the concrete mix as a partial replacement of standard cement. This market—with a potential of millions of tons per year—also offers the highest realization to the power plant. The French have done a fine job in this direction, and have developed a market of over 1 million tons per year. Total cement production in France is 25 million tons per year, or one-third that of the U.S.

Utilization of fly ash in the manufacture of lightweight aggregate is a third important market which should be pushed in the U.S. Three plants are in operation in Great Britain, which estimates future use of fly ash for this purpose at about 1 million tons per year.

The U.S., as previously noted, should spend more time and effort in developing all possible markets for fly ash. We already are far behind the rest of the Free World. The Fly Ash Symposium to be held in Pittsburgh in March, 1967, will be an excellent time to start a real push for maximum utilization. This will involve maintenance of contacts already made abroad by means of frequent visits and otherwise to facilitate exchange of information and keeping abreast with current developments in fly-ash utilization.

GREAT BRITAIN—FIRST IN TONNAGE USED

British fly-ash production in the year ended March 31, 1965, was 6.8 million tons. An additional 2.3 million tons of furnace bottom ash also was produced. This 9.1 million tons was derived from the burning of 50 million tons of coal.

Fly-ash production is expected to increase in the next decade as new coal-fired plants go into service. Henry W. G. Dedman, chief fly-ash marketing officer for the Central Electricity Generating Board, estimates that at the end of the next 10 yr fly-ash output will rise to 20 million tons. Electrical-power requirements are growing at 8% per year, and coal is expected to take its share of the increased fuel requirements.

British fly ash generally is very high in quality. Fuel is expensive and every effort is made to operate the power plants at maximum efficiency. Consequently, the carbon content of the ash usually is less than 2%.

British consumption of fly ash (called "PFA") totalled 1.8 million tons in the year ended March 31, 1965, and 2.8 million in the following 12 mo. Utilization of bottom ash was nearly 600,000 tons in each year, making the total ash consumption in the years 1965 and 1966 2.385 and 3.431 million tons respectively. Major use of both PFA and furnace bottom ash in the years ended March 31, 1965 and 1966, in long tons (1.12 times net tons) was as follows:

	1965	1966
Bricks	35,000	31,000
Lightweight aggregate	60,000	65,000
Concrete and mortar	61,000	50,000
Building blocks	871,000	938,000
Structural fill:		
Roads and embankments	822,000	1,315,000
Building sites	514,000	1,003,000
Grouting		16,000
Industrial filler		9,000
Other uses	22,000	4,000
Total	2,385,000	3,431,000

Most significant in British fly-ash utilization is the large tonnage employed in "structural-fill" applications. In addition to being by far the largest outlet, development of this market has permitted utilization on a current basis—and, by facilitating the disposal of large tonnages cheaply and quickly, solved a growing CEGB problem.

In using fly ash in structural fill, 18 to 25% of water is added. The mixture is then laid down in layers 8 to 10 in thick, compacting each with a roller. Applications include highways, embankments, airport runways and other similar mass construction where a stable base is required.

The Thelwall Viaduct, near Warrington, 80 ft. is the highest embankment in which fly ash has been employed as structural fill. It required 80,000 tons.

One million tons of fly ash was required as structural fill in the M–6 motorway in Great Britain. Absolutely no sinking of the base, particularly important at bridge abutments, is the main advantage of this construction.

Structural fill for airports can require 500,000 tons per field, and is a large potential market. The bases for two new runways at the Birmingham Airport are expected to employ 500,000 to 1,000,000 tons of fly ash.

Building blocks constitute the other large market for fly ash in Great Britain.

Consumption of fly ash in lightweight aggregate is still low in Great Britain but is expected to grow when two new plants of the Lytag Co. start operating, in addition to one already in service. Over a period of several years, utilization is expected to increase to 1,000,000 tons per year, compared to the present level of 60,000 tons.

Ahead in Great Britain—Since only 3.5 out of 9 million tons of fly ash is being utilized, the British have the problem of disposing of 5.5 million presently without outlets. The next big push is expected to be in the concrete field.

Since Great Britain utilizes about 17 million tons of cement each year, the concrete market offers a possible method of absorbing large tonnages of fly ash as a replacement for 20 to 25% of the cement. The CEGB has spent more on research in this direction than on any other fly-ash project—and has been the least successful. One reason for this lack of success has been strong opposition by the British cement industry. However, the picture could change as a result of several recent happenings:

1. Adoption of British Standard 3822 (1965) on "Pulverized Fuel Ash for Use in Concrete." Issuance of this standard makes it possible for architects and engineers to specify fly ash in concrete.

2. Increased income to the CEGB, because of replacement of high-priced cement, when fly ash goes into concrete. There also are savings in concrete cost, calculated at 60¢ per cu yd. Consequently, in addition to the incentive

for the CEGB to push fly ash for concrete, the lower cost and higher quality of the product incorporating fly ash also are incentives for ready-mix plants and concrete consumers.

FRANCE—FIRST IN PERCENTAGE USED

France burned 15 millions tons of coal in 1965 and produced 4 million tons of fly ash. The majority of the coal-fired power plants are in the Lille-Douai region of northern France, where the coal fields are located.

French fly-ash production is expected to level off at 5 million tons per year in the 1970–75 period. Other competing forms of energy will be taking larger and larger shares of the French market. As in Great Britain, coal in France is high in cost and therefore the aim in power-plant operation is maximum efficiency. Consequently, the fly ash always is low in carbon.

Utilization of fly ash in France has grown from 50,000 tons per year in 1955 to 2,100,000 tons in 1965. Cement production, in which the fly ash is ground with portland-cement clinker, represents the largest market. Second is base stabilization in highway construction. Other uses include the manufacture of concrete blocks and the replacement of cement in concrete. The trends in production and utilization in the period 1955–1965, in millions of metric tons (1.1 times net tons), is as follows:

	1955	1960	1965
Production	2.620	2.860	4.022
Utilization:			
Clinker	0.012	0.309	0.832
Roads		0.012	0.726
Blocks		0.033	0.102
Cement substitute	0.015	0.063	0.124
Other	0.023	0.117	0.340
Total	0.050	0.534	2.124

Most significant in France is acceptance of fly ash by the cement industry. Over 25% of all French cement contains fly ash. Producers use it in the belief that it makes better cement. When employed, fly ash is used almost exclusively at the cement plant where, as noted, it is ground with the portland-cement clinker. Some cements contain as much as 30% fly ash; others as little as 10. Total cement production in France is 25 million tons per year; 6 million tons contain fly ash.

In road-base stabilization—the second-largest market for fly ash in France—typical practice involves a 12-in-thick subbase containing 5% cement, 15 to 20% fly ash, and 80 to 75% sand. It is laid down over an 8-in bottom base of slag and compacted with rollers.

Growth Prospects: Modest—Though electricity production is increasing about 8% annually in France, coal is not expected to keep pace because of its high price ($12 to $14 U.S. per ton), and rising competition from oil, gas and nuclear sources. In view of this modest fly-ash growth expectation (only 1 million to a total of 5 million tons), the French expect to continue work along the successful lines of the past, namely, the use of fly ash in cement manufacture and road construction.

It is likely that over the next 10 yr the French will solve all their fly-ash-disposal problems by making use of 100% of their production.

WEST GERMANY—THIRD IN UTILIZATION

Large quantities of fly ash are not produced in West Germany, although it can be made available when and if desired. Most West German power plants use wet-bottom boilers and reinject fly ash so that it comes out with the slag. This reflects efforts by the cement industry aimed at making sure that fly ash does not become a competitor.

Ash production in West Germany totalled 10.4 million tons in 1965. Utilization was 3.5 million. Production by types, in millions of tons, is shown in the following table:

	Brown coal	Bituminous coal	Total
Fly ash	3.90	0.70	4.60
Fused granulated ash	0.08	3.60	3.68
Clinkers	1.30	0.80	2.10
Total	5.28	5.10	10.38

If the fused granulated ash from bituminous coal was equally divided into fly ash and bottom slag, then 1.8 million tons of fly ash would be available in addition to the 0.7 million now being produced. This material is known to be high in quality and the West German cement industry has been fighting to keep it out of the cement market, in contrast to the electric-utility industry, which is greatly interested in this potential—and logical—market.

The present trend in West Germany is toward dry-bottom boilers. If it continues there will be increasing quantities of fly ash to dispose of. Since West Germany produces 32 million tons of cement a year, large tonnages could substitute for the conventional cement.

Fly-ash production is expected to increase in West Germany at a slow rate because of competition from nuclear and other fuels.

Today and Ahead in Markets—Out of 10.4 million tons of fly and granulated ash produced in 1965, West Germany utilized 2.73 million, as follows:

	Fly ash	Granulated ash
Mine backfilling—pneumatic stowing		50,000
Additive—concrete production		800,000
Additive—lime- or concrete-bonded artificial stone	150,000	700,000
Additive—cellular concrete	40,000	
Sintered products		
Dusting material		20,000
Filling material		400,000
Road-building—bituminous filler	30,000	500,000
Cement	5,000	
Miscellaneous	5,000	30,000
Total	230,000	2,500,000

If coal-fired plants of the dry-bottom type are built, there will be a large increase in the quantity of fly ash available in West Germany. In addition, if there should develop a need for fly ash for either lightweight-aggregate manufacture or as a replacement for cement, nearly 2 million tons could be pulled off the wet-bottom boilers. Some—and perhaps all—of this fly ash is of excellent quality—low in carbon and very fine in size. Some of this fly ash, I feel, will become available and will go into the concrete market despite the efforts of the West German cement industry to keep it out.

U.S.S.R.—LIMITED UTILIZATION

The production of fly ash in the Soviet Union presently totals 18 to 20 million tons per year. Coal consumption for electricity generation was 200 million tons in 1965. Electricity production is growing at an annual rate of 12%. Coal use, however, will not match this rate because of increased exploitation of nuclear, oil, gas and hydro energy sources.

Data on fly-ash production and utilization in the U.S.S.R. have not been published, but have been promised as part of a proposed exchange of information.

Soviet Usage—Some fly ash is used in making blocks and for road construction in the U.S.S.R. The major use, however, is in concrete, but even here it is estimated, pending promised collection of utilization data, that the present total is not over 500,000 tons. It developed in the course of conversations with the deputy director of the Concrete Research Institute that Soviet fly ash is high in carbon (10 to 12%). Consequently it has been used only where air entrainment was unnecessary, which has severely limited its application to interior cores of dams,

the Metro subway tunnel lining and such other construction as foundations, where the concrete is not subject to freezing and thawing.

The U.S.S.R. is short of cement even though it is the world's largest producer (75 million tons per year.) Therefore, the use of fly ash to extend cement would be ideal. It was clear, however, that they did not realize that the high carbon content of their fly ash was preventing air entrainment. If it had not been for this carbon-caused air-entrainment problem, which they now perceive and are working on, the Soviets could have been using all their fly-ash production, with an increase of 25% in cement-producing capacity. Their easiest approach to carbon removal is more-efficient operation of their power plants. Another way is to separate it from the fly ash by means of cyclones.

Fly ash is used in concrete in two ways in the U.S.S.R.:

1. Production of a pozzolan cement in which up to 30% fly ash is added to portland-cement clinker and interground at the cement plant.

2. Substituting fly ash for part of the cement at the job site.

In using fly ash in concrete, water is reduced by as much as 30 to 40%, and the concrete is placed with zero slump.

Fly ash is not used at ready-mix plants, nor in concrete for pre-cast panels.

Though Soviet spokesmen expect cement production to reach 110 million tons by 1970, they also feel there still will be a shortage. Consequently, the use of fly ash as an extender is of major importance.

Soviet Prospects—The use of coal for power generation will continue to grow in the U.S.S.R., and fly-ash production could double in the next 10 yr. Since there is a cement shortage, in spite of an annual increase of 16%, it would be logical to use fly ash as an extender. This would most certainly have been the practice already had it not been for the air-entrainment problem growing out of high carbon content. It now appears that the U.S.S.R. will work to get the percentage down to an acceptable limit, and then will use increasing quantities of fly ash in concrete for all applications. If a reduction to 5% carbon or less can be achieved, there is no reason why all the fly ash in the U.S.S.R. could not be used in concrete.

THE UNITED STATES—GROWING PROBLEM TO SOLVE

Present production of fly ash in the U.S. is about 20 million tons per year. By 1980 it is expected to climb to 40 to 50 million per year. Only 1.3 million tons is now being utilized commercially, in applications, as follows:

[Tons per year]

Cement substitute, concrete	500,000
Portland-pozzolan cement production	25,000
Raw-mix, portland-cement manufacture	150,000
Soil stabilization	150,000
Asphalt filler	50,000
Oil-well grouting cement	150,000
Fill	100,000
Lightweight-aggregate manufacture	150,000
Total	1,275,000

With prospects for 40 to 50 million tons of fly ash a year by 1980, a determined effort must be made to increase commercial utilization. Disposal is daily becoming a greater problem—and one that will not solve itself. Even dumping is no solution, since a growing number of communities are banning haulage of the material and disposal of it within their borders.

No single use will solve the fly-ash problem. Each of the present uses must be studied to increase it by whatever means possible. Other markets uncovered in Great Britain and Europe should be developed in the U.S. to step up progress in disposal here. We already are far behind, and will have to work very hard to catch up.

Senator BOGGS. Dr. McCabe, president of Resources Research, Inc.

Dr. McCabe, we are glad to have you this morning. We appreciate you and your associates appearing.

STATEMENT OF LOUIS C. McCABE, PRESIDENT, RESOURCES RESEARCH, INC., SUBSIDIARY OF HAZLETON LABORATORIES, INC., AND CHAIRMAN OF THE BOARD, HAZLETON LABORATORIES, INC.; ACCOMPANIED BY JOHN S. LAGARIAS, EXECUTIVE VICE PRESIDENT, RESOURCES RESEARCH, INC.; AND HAROLD N. MacFARLAND, VICE PRESIDENT, RESOURCES RESEARCH, INC., AND DIRECTOR, INHALATION DIVISION, HAZLETON LABORATORIES, INC.

Mr. McCABE. Mr. Chairman, I have a speech impairment.

Senator BOGGS. I understand.

Mr. McCABE. I wish to have Mr. Lagarias of our company read my statement.

Senator BOGGS. Be glad to have him.

Mr. McCABE. On my left is Dr. MacFarland who is doing research; on my right, Mr. John S. Lagarias.

Senator BOGGS. Yes. Glad to have you.

If you would, proceed with the statement.

Mr. LAGARIAS. It is a privilege to give you my views on the difficult problem of air pollution and to discuss those areas where, in my opinion, research is needed. The problem of air pollution is difficult from both the scientific and enforcement points of view.

My background in air pollution is set forth at some length in the attached biography, but by way of credentials I should mention that I was the first director of the Los Angeles County Air Pollution Control District and, prior to that, Chief, Office of Air and Stream Pollution, the U.S. Bureau of Mines. If there is no objection, the attached biography will be included in the record.

Senator BOGGS. Yes.

(The biography of Mr. McCabe is as follows:)

BIOGRAPHY OF LOUIS C. McCABE, PH.D.

Education:

University of Illinois: B.S.
University of Illinois: M.S.
University of Illinois: Ph.D.

Positions held:

Geologist, Mississippi Coal Corporation, 1928–1930
Assistant, Associate and Geologist, Coal Division, Illinois State Geological Survey, 1930–1941
Chief, Utilities Section, Office Chief of Engineers, 1941–1944
Deputy War Department Power Procurement Officer, 1943–1944
Chief, Belgian Solid Fuels, SHAEF, 1944
Chief, (Colonel, U.S. Army), Ruhr and Saar, Solid Fuels, SHAEF, 1945
Mining Engineer, American Gas & Electric Co., 1945–1946
Chief, Coal Branch, U.S. Bureau of Mines, 1946–1947
Director, Los Angeles County Air Pollution Control District, 1947–1949
Chief, Office Air and Stream Pollution, U.S. Bureau of Mines, 1949–1951
Chief, Fuels and Explosive Division, U.S. Bureau of Mines, 1951–1955
Scientist Director, U.S. Public Health Service, 1955
President, Resources Research, Inc., 1955 to present
Chairman of the Board, Hazleton Laboratories, Incorporated, 1963 to present

Publications: (see attached bibliography.)

Current fields of activity: Research in the environmental and physical sciences; consultant in air pollution control to industry and government; direction of research in biological and physical sciences.

Present or former consultant to:

New York University
International Labor Organization
World Health Organization
International Joint Commission (U.S. and Canada), Technical Advisory Board on Air Pollution

Memberships:

Fellow, American Association for the Advancement of Science
Fellow, Geological Society of America
American Institute of Mining and Metallurgical Engineers
Air Pollution Control Association—Director and Vice President, 1963–1966
American Society for Testing and Materials
Washington Academy of Sciences
Illinois Mining Institute
American Chemical Society
The Society of Sigma Xi

Partial list of present or former committee activities:

National Research Council Committee on the Chemical Utilization of Coal
Coal Preparation Committee, American Institute of Mining and Metallurgical Engineers
Chairman, Committee D–22, American Society for Testing and Materials
Industrial Health Committee, American Medical Association
Air Pollution Committee, Industrial Hygiene Foundation
National Advisory Committee on Air Pollution, United States Public Health Service

Decorations:

Legion of Merit (U.S.)
Order of the British Empire
Order of the Crown of Belgium

Mr. LAGARIAS. The Clean Air Act lays emphasis on two major unsolved air pollution problems needing special attention—motor vehicle exhaust and air pollution from fuels containing sulfur.

With respect to air pollution produced by the burning of fuel containing sulfur, the act directs that the Secretary of Health, Education, and Welfare initiate a program of research to find improved methods removing sulfur from fuel at a practical cost.

Sulfur dioxide and sulfuric acid aerosols are both irritating to the respiratory mucosae but are not generally regarded as being of great intrinsic toxicity. Because of their high aqueous solubility, these two airborne contaminants are primarily upper respiratory tract irritants. However, it has been shown that the depth of penetration of these materials may be markedly increased in the presence of particulates. Thus, a system containing both sulfur dioxide and fly ash might well prove to be irritating to the lower respiratory tract, including the alveoli.

Several studies have been reported on the toxicity of sulfur dioxide and sulfuric acid mist and their effects on certain of the parameters of pulmonary function. In general, both sulfur dioxide and sulfuric acid mist in sufficient concentrations cause an increase in pulmonary flow resistance and a decrease in lung compliance.

A number of studies have been performed using the human as subject. Some controversy developed when Amdur reported that the inhalation of sulfur dioxide in the range 1 to 8 parts per million by normal human subjects caused an increase in pulse rate and the de-

velopment of shallower and more rapid respiration. These observations were challenged by Lawther, who, in a series of carefully controlled experiments, employing 18 normal subjects exposed to 5 to 10 parts per million of sulfur dioxide, was unable to find consistent changes in tidal volume, respiratory rate, or pulse rate.

It is apparent from the brief review presented above that some deficiencies exist in both the experimental and clinical studies that have been reported on the effects of sulfur dioxide, sulfuric acid mist, fly ash, and their various combinations.

Because of the inadequacies in the presently available data, the problem of establishing air quality standards of scientific validity has resulted in the promulgation of different standards for sulfur dioxide, no agreement on a final standard for sulfuric acid mist, no recommendations relating to fly ash specifically, and no recommendations for combinations of these pollutants.

The particular defects that may be noted in published studies include a failure to work at realistic concentrations of the pollutants, the use of small rodents without concomitant employment of larger species, particularly subhuman primates, and a haphazard approach to the question of examination of mixtures instead of an orderly and systematic exploration of the important possible combinations. A proposal which we submitted from Hazleton Laboratories, Inc., was designed to overcome these special objections.

The concentrations suggested in that proposal cover the ranges of interest. Guinea pigs and monkeys used in the experimental studies will provide the requisite guidelines for a subsequent clinical program. By limiting the number of pollutants to be examined to three, and also by limiting the number of concentrations or particle sizes to be tested, it will be possible to investigate an adequate variety of the important combinations. Criteria of response have been selected which are sensitive and nondestructive. At termination of the proposed series of investigations, it will be possible, by statistical evaluation of the results, to make well-supported recommendations for air standards and to design safe and meaningful studies with the human subject.

This proposed research is now being sponsored by the Edison Electric Institute, the National Coal Association, the Tennessee Valley Authority, and the Los Angeles Division of Water and Power. Another project related to that just described is being sponsored by the American Petroleum Institute.

The first of these studies is designed to provide objective information on which air quality standards for certain pollutants may be rationally based. The pollutants under examination are sulfur dioxide, sulfuric acid mist, and fly ash. Mixtures of these substances will be examined in a program which will run for nearly 6 years. The studies are unique in the following ways:

(1) Low concentrations of the pollutants, at levels actually measured in polluted air, are being examined; unrealistically high concentrations which are never observed in practice are not being examined.

(2) Exposures are for essentially 24 hours a day, 7 days a week, for periods of a year or a year and a half in each test.

(3) Although some work is performed on small rodents, the bulk of the studies is centered on the responses of subhuman primates.

(4) In addition to the performance of the more conventional types of hematological and biochemical procedures, an unusually complete battery of highly sensitive pulmonary function tests constitutes the main technique for assessing the responses of the animals.

(5) Advanced statistical treatment of the results, aided by computer techniques, is used to derive the maximum amount of information from the investigation.

The second significant program in progress at Hazleton Laboratories is being supported by the American Petroleum Institute. The investigation is primarily concerned with adducing evidence on the question of synergistic effects among mixtures of pollutants.

Initially, the substances under examination include sulfur dioxide, carbon monoxide, nitrogen dioxide, a lead-containing particulate, and a particulate sulfate. Approximately one-third of all the theoretically possible mixtures of these materials has been carefully selected for study in this 3½-year program. Techniques, similar to those mentioned above in connection with the first program, which emphasize the use of sensitive pulmonary function tests in the primate are also being employed in this synergism study. Again, long-term continuous exposures to low and realistic levels of the compounds constitute one of the valuable features of the investigations.

In 1948, the Los Angeles County Air Pollution Control District, of which I was then the director, recommended rules which prohibited the discharge from any single source to the atmosphere of sulfur compounds in excess of 0.2 percent by volume (2,000 parts per million). This regulation was made specifically to overcome injury to crops in a refinery area, the injury being attributed to sulfur dioxide and not to ozone or other oxidants. Ground concentrations of SO_2 never again exceeded 0.5 part per million in that area during my time as director and the complaints of crop damage stopped when the recovery measures were completed.

The equivalent of some 1,300 tons of sulfur dioxide is recovered daily in Los Angeles County largely through scrubbing of sour refinery gases. The Air Pollution Control Board of Los Angeles County recently has set a maximum limit of 0.5 percent sulfur in fuels burned in the county. Dade County, Fla., has adopted regulations which set ground concentrations of SO_2 at 0.1 part per million in the ambient air. The Public Health Service has been instrumental in the release an Executive order which limits to less than 0.5 percent the use of sulfur in fuel in Federal installations in some cities.

In spite of the extensive research on sulfur compounds that has been done in the past and continues to be accomplished, the effect of these compounds on humans is not known for low concentrations (for example, in the range of 0.5 to 0.1 part per million).

Low sulfur coals are limited in supply. As a result, a regulation of 0.5 or 1.0 percent maximum in conventional fuels, as opposed to the atomic fuels, would exclude from the market more than 80 percent of the coal now mined in the United States. It is particularly devastating to require limits of this kind unless a need for such regulations is demonstrated or until methods for sulfur removal are perfected. The Los Angeles County and the Dade County regulations, in effect, prohibit the use of all conventional fuels except natural gas.

Our experience with communities and with most industrial concerns faced with air pollution control has shown that a change in attitude has taken place over the past 10 years. Management, to a large part, has recognized the necessity for air pollution control, especially as a result of the very rapid increase in urbanization and travel. The change is reflected in the willingness to accept the need for installing more adequate and more satisfactory abatement equipment. We are often asked to recommend proper equipment. In some instances, we have had to say that additional reseach and development is required before a satisfactory recommendation can be given.

A question that has been frequently posed involves the choice of equipment and the desired level of performance for abatement equipment. A user wishes to know what constitutes adequate emission control so that the effluent does not adversely affect a community. Most users would like the assurance that the abatement equipment that they install is not only satisfactory but will be adequate for a reasonable period of time. Unfortunately, in some communities this assurance cannot be given by the local representatives, from State, or even from Federal authorities. They cannot state that the performance of any equipment will be adequate if regulations are continuously revised, except in a few instances where the recommended equipment is so costly as to be unrealistic.

A basic need exists for air quality regulations that can be reached now. It may be that we may never know what constitutes safe air quality. We cannot wait to determine the absolute levels of safety We must work with the knowledge that we now have and establish regulations which are meaningful. In exercising the judgment necessary to select meaningful values, there should be no compromise with any level which will affect the health of human beings. The level of air quality which we must have to protect human life has not been clearly established except for a few exotic or very toxic materials. We will probably be doing research on this problem for the rest of man's existence. But, rather than wait for the ultimate knowledge, we must do what we can with the information available.

We believe that air quality levels should be established which are reachable. We believe that more science and technology should be applied. We also believe that what can be done to improve air quality should be done. By this we mean that the existing regulations now in existence should be enforced.

The air quality levels that we establish as goals should be based on a number of criteria, of which health is only the first. Other factors include economics, availability of equipment, and the needs and desires of each community.

The goals should be redefined as more exact information becomes available. The goals should not be unreachable, nor should they be predicated on highly controversial and novel research. They should be pragmatic but subject to reevaluation.

A considerable amount of confusion exists between various terms—criteria, standards, regulations, effects—with all these terms frequently being used interchangeably. The use of criteria by State and local governments will vary with individual judgment.

There has been a tendency to use some of the terms out of context. It may be more sensible to promulgate regulations only. The term.

"standards," for example, implies the knowledge that the levels described as standards are safe. Such may not be the case at all.

Use of the term "criteria," for regulatory purposes, involves judgment factors which usually only the authors and the reviewers of the original documents thoroughly understand.

We believe that it is best to establish regulations that are practical within the limits of the technology and which fill the needs of each community. We believe that regulations should be revised as the standards of living change. To confuse them with other terms, however, does a disservice to us all.

Users of control equipment would like the assurance that the actions they take now will be satisfactory, based on today's knowledge. They do not have this feeling today when criteria are proposed which are beyond their reach.

Consideration also should be given to assure that the investment in time, effort, and money in abatement equipment will be amortized through the practical life of the equipment when the equipment has been selected on the basis of technology currently available.

The following lists research needs in air pollution:

I. AUTOMOBILE EXHAUST

A. Additives to fuel and their effect on vegetation and man.

B. Production of satisfactory exhaust or substitution of power elements.

II. SULFUR OXIDES AND OTHER AIR CONTAMINANTS

A. Developments in recovery of sulfur dioxide.

B. Clinical and experimental studies on exposure of man and animals to air contaminants.

(1) Supplemental current research by private and public research laboratories.

(2) Further studies on man and animals.

(3) Tolerance levels of animals and man.

(4) Concentrations of sulfur oxides encountered on inspiration and expiration by cigar, pipe, and cigarette smokers.

C. Ambient air investigations related to sulfur oxides and other air contaminants.

(1) Tolerance levels of plants; effects on life and condition of decorative trees and resistant strains of trees and other vegetation in metropolitan areas. Development of plants for cities.

(2) Tolerance levels of animals and man.

(3) Survey of levels of pollution (SO_2, H_2SO_4, CO, hydrocarbons, carcinogens, et al.) in living space (for example, conference rooms, airplanes, et cetera).

D. Instrument development required.

(1) More specific and reliable instruments. (Today we do not have satisfactory continuous monitoring equipment for particulates and for sulfur dioxides emitted from power stations or other industrial sources.)

(2) Measurements responsive to effects of pollutants.

E. Abatement equipment.

1. To handle odors, fumes, and gases.

III. BASIC RESEARCH ON AIR CONTAMINANTS

A. Gross and long-time effects on our environment.

B. Degradation and cycle of pollutants in relation to time.

C. Weather modification and other effects of pollutants on environment.

D. Interrelationship of air and water pollution.

In regard to automobile exhaust, it is my opinion that the Federal Government should not attempt to modify, develop, or build in its own laboratories a substitute for the internal combustion engine but should devote its efforts to a basic understanding of the effects of any contaminant that may be released to the atmosphere from any motor used in the movement of a vehicle and to setting standards of performance.

For 2 or 3 years I have been observing and photographing the vegetation in the Washington area. During this time I have noted that the leaves on trees along streets carrying heavy automobile traffic show excessive necrosis (dead tissue), particularly at stop signs, lights, and bus stops.

On the street side nearest the traffic lane, the leaf injury is usually greatest. In the late summer, frequently the limbs nearest the traffic are completely denuded of leaves and sometimes the wood is killed.

Last summer I noticed that the leaves of the maple trees along 34th Street, back of the National Cathedral, had necrotic borders. I gathered some of these leaves, separated the necrotic border material from the living tissue, and had the two portions spectrographically analyzed for metals. In October of this year, I noticed that the European chestnut showed excessive border necrosis along heavy traffic streets in Geneva, Switzerland, and Paris, France.

It is obvious that the toxicity reflected by the conditions in leaves reported above are from traffic gases since there is no apparent injury where the same species grow 20, plus or minus, yards removed from the traffic. Recently I noticed this, particularly in Coral Gables, Fla., where the dead tissue in mahogany and mango was not apparent beyond the sidewalk.

I have a statement from the Petroleum Division of the Bureau of Mines that boron, nickel, and manganese are common additives to gasoline. The preliminary spectrographic analyses which were made of sample necrotic leaves showed these to be high in nickel, boron, and manganese, as well as a number of other metals. The Paris samples, for example, were high in copper. At this time we do not fully know the extent and composition of additives that are introduced into gasolines, diesel fuels, and lubricants.

I believe that the first step in a study of the nature of injury to plants by metallic compounds should be reflected in the sampling for trace quantities of metals along the traffic lanes where we have seen injury to vegetation.

Again and again, we have observed the value of plants as indicators of atmospheric pollution. However, our primary objective in using plants is to identify those airborne elements which may be injurious to human health. The response of sensitive vegetation may be the first indication that we have contaminants other than lead, CO, ozone, and hydrocarbons to be appraised as far as human health is concerned.

Some weeks ago, it occurred to me that the fossil fuels having come from the organisms from which they were formed might be prototypes

to plants growing today. Sulfur is used in the metabolic process of all vegetation, and Beltsville has determined that tobacco plants contain 0.2 to 0.7 percent sulfur.

Following this, our laboratories have made a few tests which indicate that the respired smoke from cigarettes may have contained sulfur oxide concentrations of between 150 and 250 parts per million. If we assume that all the sulfur in tobacco is sulfurized SO_2 in burning, the exposure to oxides of sulfur may be very much greater in the human lung than the 0.1 parts per million which the Public Health Service has set for the ambient air.

It appears to me that here is an area which requires extensive investigation. It may be that our long conferences and confined space are far more hazardous than the exposures to outdoor atmosphere. It is apparent that if a study of confined spaces were conducted, higher concentrations of sulfides, hydrocarbon, and oxides may be found in conference rooms, automobiles, and airplanes than is ever experienced in the ambient air from burning of coal or heavy duty oil.

I appreciate the opportunity of submitting the foregoing information to your subcommittee.

Senator BOGGS. Thank you very much.

I thought that was a very impressive paper, Doctor, and I am sure if all the members of the committee could have been here at this moment—they have other necessary duties to attend to—they would have quite a good many questions to ask.

Your paper and your contribution will be of great help to the committee.

I am sure the studies you are undertaking have a great potential and will contribute to helping to meet this air pollution problem. I know it is being followed by the Public Health Service.

The thing I was interested in when you discussed criteria and standards and how the words are confused and misused, you suggested that it would be better to write regulations from time to time to meet the situation, but how could you write meaningful regulations without using standards or criteria?

Mr. MCCABE. Well, I think you could write them.

The unfortunate part, I believe, in using criteria is that the people out in the country, say at the State or local level, assume that those are, well, ex cathedra demonstrations of protection of people against health impairment.

Now, the Public Health Service has explained that that is not so. I think that if we do not use that one word, we would avoid a lot of confusion.

Senator BOGGS. Not use the word "criteria"?

Mr. MCCABE. Yes.

Senator BOGGS. If you don't use the word, what do you replace it with?

Mr. MCCABE. I think part of our problem is the definition or lack of understanding of what the Public Health indicates they mean by that term. If they set a certain criterion that may be beyond the level of attainment, it will be adopted by some areas. I have seen that come up again and again.

Senator BOGGS. I understand that.

Mr. McCabe. They say the criteria of the Public Health Service are thus and so. Quite often there will be a representative of Public Health asking that the criteria be written into regulations. Sometimes we are not ready for that or don't need it.

Senator Boggs. What do you use, goals?

Mr. McCabe. "Goals" I think would be better than "criteria" because of the confusion now existing with regard to the use of the word "criteria."

Senator Boggs. For ambient air, you are suggesting that the criteria approach is not the right approach, as I understand your testimony, and, rather, it should be goals; is that it?

Mr. McCabe. I think that is it.

Senator Boggs. For regulations, you are suggesting that standards should not be set, but what would you put for specific emissions where you can identify the emissions and you would be able to write a regulation as you suggest, how would you approach that? You would have to approach it by standards or just numbers?

Mr. McCabe. Well, I think perhaps you could embrace that in goals.

Senator Boggs. Even in the regulations? How would it be enforceable?

Mr. McCabe. Well, a regulation locally is in force. I would not enforce goals unless they were adopted as a regulation by the local agencies.

Senator Boggs. When you were speaking of regulations in place of criteria or standards, were you visualizing that there should be national regulations?

Mr. McCabe. No, sir. I am afraid that with the way the power is delegated, an air quality value may be misused. We are actually giving that kind of authority to powers that make rules without review, and I know there is great concern about that. I would like to see the Federal Government do its research, give agency information, probably recommend that in this air shed or in the common area, say St. Louis, that there is certain regulations put into effect.

Now, of course, in some cases you would not need as stringent regulations; you might not need any regulations on certain contaminants. The local people know that.

I think maybe the approach you now have to the water standard is attractive. The way to do this is that the local areas might come in with regulations acceptable, say, to the Secretary of Health, Education, and Welfare. If they are not brought in, then perhaps he could enforce regulations of that sort.

Senator Boggs. Similar to the Water Quality Act?

Mr. McCabe. Yes.

Senator Boggs. Do I understand that you are suggesting that regulations be established that will be adjusted either upward or downward as more information becomes available on both health effects and improved technology?

Mr. McCabe. Yes.

Senator Boggs. It is that flexible?

Mr. McCabe. Yes.

Senator Boggs. I don't know whether you are familiar with the research costs; I know they are high, but as far as the Federal Gov-

ernment is concerned and the encouragement of research, do you have any estimate of what is a reasonable practical figure without too much duplication and so forth and how much the Federal Government should spend on encouraging research?

Mr. McCabe. Well, it is difficult. I know of the proposals in some of the fields. I think with the goals that are outlined, the amounts of money needed are not unreasonable.

I do feel, though, that industry should come in to help with this research; that allocation of funds to industry should be based on confidence and not denied on the ground that they are private enterprise people.

Senator Boggs. Well, we thank you very much, Doctor, and your associates for your presentation this morning.

Thank you.

Mr. McCabe. Thank you.

Senator Boggs. Well, our last witness this morning is Dr. Cassell, associate professor of community medicine at Mount Sinai School of Medicine, New York.

Doctor, we are glad to have you, sir.

STATEMENT OF DR. ERIC J. CASSELL, ASSOCIATE PROFESSOR OF COMMUNITY MEDICINE AND ASSOCIATE PROFESSOR OF MEDICINE, MOUNT SINAI SCHOOL OF MEDICINE, NEW YORK, N.Y.

Dr. Cassell. Thank you.

I am sure that much testimony has been presented to you during these hearings and previously which has been, at the very least, contradictory and confusing. The evidence which seems so much at odds has been presented by experts who are of undoubted qualifications, presenting their honest and well-thought-out opinion based on their own and others' research. Therefore, let me draw a first, and I think for the formulation of legislation a very important, distinction.

The evidence bearing on the health effects of air pollution, particularlarly the oxides of sulfur, is in conflict: Conflict not just between the experts; conflict not just between industry and public health forces; but conflict in the evidence itself.

There tends to be justifiable impatience with the demand of the experts for more research to resolve the conflicts because the problem is now, and none of us want to wait any longer before we effectively control air pollution.

But it is not always so; the experts do not always argue. There has never been a word of argument since the first dose of penicillin was given, over what that drug could do in susceptible pneumonias.

What, in effect, is obvious doesn't require argument.

The problem becomes, therefore, not one of simply deciding on an acceptable numerical level of pollution, but of deciding how to handle a situation of this type where numbers must be chosen, and where real meaningful conflict exists over the choice of those numbers.

I would like to review the nature of the biological research problem that is posed by air pollution, which may clarify somewhat. As John Goldsmith clearly stated several years ago, this is a problem in toxicology, determining for man in his natural setting (now increasingly

urban) the relationship between the dose of the noxious agent in the atmosphere and the biological response in man.

Classically the toxicologist works in the laboratory and is able to present the dose of the pure toxic agent over such a wide range that he is assured of going from no effect on the experimental animal to the most severe effects and can assess reliably of what the substance in question is capable.

But in air pollution studies that occur in the natural setting, almost none of the ideals of the toxicology experiment are met; conversely in laboratory studies of the effects of pollutants on man or animals almost none of the realities of the urban setting are approximated.

Let us look at what complicates these studies.

The examples that follow are based primarily on sulfur dioxide.

First of all, the dose, the sulfur dioxide, except under the most bizarre and rare circumstances, is present in the urban atmosphere in very low concentrations and over a very narrow range. The peaks are rarely 10 times the daily averages. The peaks themselves, are usually not above 1 part per million, 1 part per million is about the bottom of the range frequently used in the laboratory. The highest levels to which populations are exposed, therefore, are so low that they are seldom used in the laboratory experiments.

Second, sulfur dioxide does not exist alone in the atmosphere. While it may be present, at the same time numerous other substances which may or may not have an effect on man are also present. Concentrations of the other substances will tend to increase at the same time as the sulfur compounds are increased. It is difficult, therefore, for the scientist to know whether an effect he has observed was caused by the sulfur compounds, or by the other materials present.

The third and related complication of such studies is that all the various substances do not coexist without interaction. The atmosphere is often naively pictured as a large pot in which things are dumped and in which they stay unchanged. But in reality the atmosphere is a dynamically active chemical retort in which substances change themselves and react with other materials to produce new and sometimes unknown substances, with this atmospheric chemical factory variously affected by wind and sun and humidity to further complicate it.

The meaning of this dynamic chemistry for the Los Angeles oxident type of air pollution was well demonstrated by Dr. Haagen-Smit and others; but we have avoided this same conclusion, that the problems faced in the predominantly sulfur oxide pollution of the northern industrial cities may also derive from the complex interaction of pollutants and weather.

Fourth, how do we know what is really in the atmosphere? Frequently knowledge is a function of technology. We know about sulfur dioxide because we have instruments to measure it, and have had for some time. But we all know that there are substances in the atmosphere of whose nature and presence we know nothing, and that the number of such substances is probably increasing as our technology expands.

For example, what happens to a plastic bag when incinerated; and what is the effect in the atmosphere of gasoline additives?

The fifth complicating feature of the natural experiment is the meaning of what the pollution measuring instruments say. When a re-

search study reports that the population was exposed to, for example, 0.25 part per million of sulfur dioxide, what does that mean?

Generally the instrument didn't even really measure sulfur dioxide. If it was of the conductivity type commonly in use, this instrument only reflects sulfur dioxide when that gas exists alone—but as has been pointed out, that ideal is rarely met in the atmosphere.

The measurement is interfered with in numerous ways that cast serious doubt on any interpretation of experimental results that are presented as though the exposure was really to sulfur dioxide. In our studies, at one point, we had two instruments side by side, one measuring "true" SO_2 and the other a Davis meter employing the conductivity method commonly in use; not infrequently their readings bore no relationship to each other. They could be opposite, one up and one down.

In our papers we carefully use the words "whatever is represented by the measurement of sulfur dioxide" but when we are quoted, that important note of caution is left out or forgotten. Similarly, in some studies, the average sulfur dioxide of one area is compared to that of another and then the research findings are casually related to sulfur dioxide. But sulfur dioxide levels are an index of many things: the weather; type of fuel used in home heating; degree of industrialization; socioeconomic level of population; crowding; and probably a host of other factors, all of which have a bearing on the diseases which are thought to be associated with air pollution.

Many attempts, some successful, have been made to dissociate these related factors from the effects of the pollutants, but in a number of studies these confounding factors are ignored. But legislation which proposes a numerical standard for SO_2 does not deal with "whatever is represented by the measurement of sulfur dioxide", it deals with the gas sulfur dioxide, and frequently the legislation, cognizant of the difference in instruments, specifies an instrument which is much more accurate than the instrument which was used in the research on which the legislation was based, so it just compounds the problem.

Finally, the effect of sulfur dioxide on man is further complicated by the effect of the atmosphere itself. Temperature and humidity have an unquestioned and well-known effect on health quite apart from the effect they may have on the pollutants in the atmosphere. The most sharply defined mortality peaks in New York City between 1962 and 1965 occurred during heat waves on two successive summers; and in that 3-year period there were more than a dozen air pollution episodes.

I might also say that other sharply defined episodes occurred during Christmas, which is another dangerous period of the year.

These additional factors that influence the dose of pollutant appear to be inordinately complicating, but they cannot be dismissed because they are inconvenient. You will find, also, that expert witnesses agree on them, so there is something that we experts really do agree on, that it is a complicated matter and that, therefore, they represent a point of strength rather than weakness. Strength because this agreement underlines a sound body of information from which to depart. Weakness only when a path is pursued that disregards this important information.

The problems that beset the epidemiologist concerned with the dose of the noxious agents in his natural toxicology experiment are no more than the difficulties he confronts in looking for the effect of the pollutants on man.

Briefly stated there have been no responses in man or animals thus far discovered which are unique to, or solely caused by, exposure to the oxides of sulfur, except perhaps odor.

Secondly, there has been no way thus far to get experimental populations who are alike in all respects except their exposure to the oxides of sulfur.

I would like to amplify somewhat on these two points because they lead to an important conclusion. The effects of the oxides of sulfur on man and animals appear to be a consequence of irritation of the mucus membranes. (And to produce this irritation in the laboratory has required levels of SO_2 generally well above those found in the atmosphere.)

Cough, airway constriction, increased sputum or mucus are all secondary to the irritant effect of the noxious agent on the sensitive mucus membranes. But these symptoms and research findings are also produced by cigarettes or other irritants, allergy, infections, other pollutants, emotional factors, and so on.

Diseases which are at least in part contributed to by air pollution are also clearly influenced by other factors. Thus one of the major research tools is denied us, a marker by which we can clearly define an effect of a pollutant on the study population uncomplicated by any other effects.

The "control population" is dear to the heart of science: a population the same in all respects except its exposure to the agent in question. But this, too, we do not have.

Air pollution is so ubiquitous that one can never find an urban group that has no pollution. There are such great differences between city and country dwellers, besides their exposure to air pollution, that it is difficult, if not impossible, to disentangle these factors with any more ease than we can disentangle the differences in the same population between days of high and low pollution.

There is no difference between searching for the health effects of air pollution and seeking the health effects of noise, urban crowding, poverty, depersonalization and the numerous other results of increasing urbanization and the so-called overdeveloped society. Air pollution, therefore, is important also as a prototype of the modern multifactorial problem; its effects are only part of the chain of events leading to illness, loss of function or death.

All attempts to reduce air pollution to the old-fashioned Public Health ideal of "one cause—one disease" have just not worked. It seems obvious and important to recognize the fact that if the simplistic research approaches have failed, so probably will simplistic legislative approaches. It is equally clear that as we begin to work out research and legislative approaches to this particular multifactorial problem, we will be better prepared for the other multifactorial problems that increasingly beset us.

Recognizing the complexities of the biological problem is also a strength rather than a weakness, if it forces us to start building con-

tingency legislation, where varying standards depend on varying circumstances, before we have gone so far down that old-fashioned road that turning back seems impossible in this area.

Despite all the difficulties and weaknesses in the research, sufficient evidence has accumulated over the past number of years to allow certain conclusions: The famous air pollution disasters allow no escape from the fact that uncontrolled air pollution may have extremely harmful effects.

A great deal of research was stimulated by these disasters and much of the research attention has been paid to sulfur dioxide. These numerous studies, using man and animals as experimental subjects have failed to provide evidence that sulfur dioxide alone, at levels anywhere near those found in urban atmospheres, has any adverse effects on man.

As a matter of fact, laboratory evidence plus experience with industrial exposures suggests that at the low concentrations found in urban environments sulfur dioxide is quite innocuous. However, epidemiologic studies using methods that vary from the crude to the refined, and biological endpoints varying from death to the faintest physiologic change, have provided repeated clues and indications that air pollution as a generality is related to ill health; these studies have also failed to provide evidence that sulfur dioxide, the gas, in and of itself, in the air of our cities is ever the sole cause of disease, disability, or death.

A few years ago, for the Gordon Conference on Air Pollution, I presented a review of the epidemiologic evidence relating atmospheric sulfur dioxide to health. In that review I concluded that for an effect of atmospheric sulfur dioxide on health to be demonstrated epidemiologically, particulate matter must also be present in the atmosphere.

For the sake of brevity I have omitted a review of that evidence, but I will be glad to go into it should you desire.

Senator BOGGS. If you would care to make it a part of the record, that will be fine.

Dr. CASSELL. I will do that.

However, laboratory support for that thesis has come largely from the continuing elegant studies of Dr. Mary Amdur throughout the last decade.

Since that review, there has been no reason to change this opinion. It would appear that sulfur dioxide and particulate matter under certain conditions react together in the atmosphere, and are then perhaps capable of producing an adverse effect on health.

I would like to speculate further on the atmospheric chemistry involved. The evidence seems to indicate that the critical material in those reactions is not the sulfur dioxide, but probably the particulate matter.

In the presence of a proper catalyzing particle it may be that the SO_2 is absorbed and converted to SO_3. With sufficient added moisture the SO_3 becomes sulfuric acid. If the particle is the proper size, it may be inhaled and deposited in the bronchioles and alveoli, where it remains to irritate. Under those circumstances, a tiny sulfuric acid manufacturing plant has been inhaled.

There is some further evidence that bears on this point: We speak of airborne particulate as though it was one substance, when indeed it is extremely variable. The origin of the fuel and the way it is burned affect the size, shape, and composition of the ash.

In England, where, as you have undoubtedly heard, the evidence for a health effect of air pollution seems much sharper, the coals used for fuel contain sizable amounts of titanium and nickel oxides which become part of the airborne particulate when they are burned.

Both of these are good catalysts for the conversion of SO_2 to SO_3 and eventually to sulfuric acid. Most United States coals have considerably less of these compounds and therefore the London particle may well be a different and potentially more active one than the New York particle. It must be emphasized that what I have just presented is speculation although there is considerable laboratory support in the work of Dr. Amdur.

If these conclusions and speculations are correct, then we should be able to resolve the paradox that has plagued us: Why has there been continued evidence of a general effect of air pollution that could not be substantiated when individual pollutants were examined? Because the effects may well have resulted from a complex of substances.

These conclusions should draw us away from simplistic air pollution control legislation and point increasingly to the need to legislation which is appropriate to complex situations. This is particularly important since the increasing number of multifactorial problems will eventually demand such sophisticated and forward-looking solutions. Similarly much more of our scientific energy and money must be expended in developing research techniques more appropriate to multifactorial problems.

This summary of the research problem involved in the evaluation of the health effects of air pollution has attempted to make clear several very important things: the complex interactions between pollutants; the difficulties in the measurement of atmospheric substances; the multifactorial nature of the diseases in which air pollution may play a part; the possible contingency effects that are represented by the effects of sulfur dioxide—innocuous by itself, but possibly effective in combination with other substances; and finally, the strengths and weaknesses that emerge from the entire problem and research.

One conclusion can be clearly drawn; the research clearly points toward one thing: It is not reasonable or sound to legislate air pollution control by writing law or standards for one pollutant at a time, out of the context of the whole. It is not reasonable or sound to set sulfur dioxide standards for air or fuel that do not take into account local conditions or that are out of the context of the whole air pollution problem.

But what, if any, are the alternatives? That is always the question. The alternatives are real and they are effective.

The goal is to get and keep the air as clean as possible, and as is feasible. The simple statement of the goal implies that this cannot be done by chasing down one pollutant at a time. Can you imagine holding these hearings for every single pollutant, one at a time?

The research points clearly to the most efficient way we can allot our legislative and research force and energy:

First, we must make the occurrence of an air pollution episode in the future an impossibility by developing and supporting the warning systems apparatus and encouraging local legislation where it does

77-515 O—67—pt. 3——29

not exist. We can make sure that interstate transport of pollutants cannot subvert an otherwise effective episode control system. The knowledge to do this is presently available.

Second, we should reduce particulate and sulfur oxides and all pollutant emissions to the greatest degree that is feasible, employing the best technology available, the maximum technological capability.

The key words here are feasible, and use of the best technology available. The degree that is presently feasible is quite good, and if this degree were met in all industries, the air would be very much cleaner, without necessarily threatening the economic structure of an industry.

Further the statements "feasible" and "maximum technology" have built in them continued progress, whereas fixed standards do not have progress built in them. Changing standards is a notably difficult thing to do. Changes in the feasible and technology capability occur in and of themselves, as part of progress.

The concept of the interrelationship of pollutants makes it possible to expend less energy in the control of sulfur dioxide where particulate loading is minimal, in comparison to areas where there is much particulate.

Sometimes, and Dr. McCabe made this point before, we do not realize how much progress we have made toward agreement during the last few years. Today, almost every responsible view and interest recognize that the atmosphere cannot be used as a garbage can. On that assumption, the research effort must be toward better fuels, better combustion processes, better exhaust controls. In other words, the effort must be continually to improve both the feasible and the maximum technological capability.

The philosophy is that a clean environment contributes to health and well-being. Therefore, it should not be necessary any longer to prove harm from air pollution to insist on its control. The fact that it is there and that it is soiling the environment is sufficient. But the control must be a joint effort with Government helping to determine the feasibility and helping in the development of maximum technological capability, not just Government pointing a finger by use of fixed standards criteria.

Industry, the academic community, and government can join together in this kind of an effort. They are forced apart by the present pursuit of numerical standards.

We must no longer allow the atmosphere to be used as a garbage can without at least knowing the nature of the garbage. The Federal Drug Administration screens drugs that will be used on a few people, to prevent adverse effects; but we allow substances to be added to the atmosphere, to be breathed by millions, without knowing what they do. Substances that will end up in the atmosphere during their natural life cycle, from gasoline additive to materials that will be incinerated, should be investigated as to their potential danger, before we allow their use.

Finaly, the biological and chemical research effort should be directed toward the complexity that is represented by air pollution, rather than toward oversimplified research to support oversimplified legislative approaches or numbers.

We are developing approaches to multifactorial problems. The first steps must necessarily be hesitant, but they must be taken. The history of air pollution research points clearly to the need for a new approach and, I think, clearly to its potential success.

Senator BOGGS. Doctor, thank you very much for your impressive and thought-provoking testimony. I am sure it will be a helpful contribution to this committee.

As you got near the end of pages 15 and 16, discussing the legislative approach, you mention on page 16:

> We should reduce particulate and sulfate dioxide emissions to the greatest degree that is feasible, employing the best technology available.

How do you write legislation to get at that specifically without making specific admissions or referring to specific emissions?

Dr. CASSELL. I think that I also agree with Dr. McCabe that the whole problem of the words "goals," "standard," "criteria," have gotten so confused, that as words, they have become useless, but I think they have use in the following way.

They are a measure of success, something to measure achievement. If they are used that way rather than by enforcement as goals; a statement of what we would like our atmosphere to be rather than as a directive of what it must be. They may have use. If they are used that way, then the enforcement of feasible and maximum technological capability dovetail with them.

In all situations with which I am familiar in industry there will be one plant of an industry or one factory where control is really much better than it is in a neighboring plant or somewhere else. That plant has demonstrated a technological capability and a feasibility which cannot be denied by the rest of the industry because it is there, and it is working.

It does not have anything to do with the standard per se, there is no argument that can be made. There is a factory with proper controls, it is working. It is proof that it can be done. The use of this technique is made possible, by the fact that we don't need to prove pollutants harmful, one by one, anymore.

Senator BOGGS. As I understand it, in essence you are saying that we cannot discount SO_2 but we should direct more attention to the interrelationship of all pollutants including SO_2 and their combining effects on health.

Dr. CASSELL. Right, and I think that is one of the other problems about the separate standards; they cannot really recognize the relationship.

It is impossible to have a standard this high in this area, as far as other pollutants are true contingency statements for the pollutants, themselves.

As a matter of fact, the writing of separate standards tends to deny the fact that they really do interrelate. So, what we are really saying is that we believe there are interreactions and that therefore the attempt must be made to get all the pollutants down on as broad terms as possible.

We realize that that is difficult also and that it would be easier in some areas to get particulate down before we get sulfur dioxide down, so we realize from our facts that is allowable. You can make your pur-

suit in that direction; that is part of the feasibility. It recognizes what we know and recognizes what we do not know.

I think I must apologize for my own particular industry, that as research people we have been a little neglectful in telling what we don't know.

Senator BOGGS. It is good to tell what you know.

Dr. CASSELL. It is easier.

Senator BOGGS. The point is, though, on this air pollution control problem we have to start off with what we do know, it would seem. There is so much unknown, but if we take these items that we do know something about and try to approach them realistically, hoping and continuing our research effort, we cover the mileage sooner or later.

Dr. CASSELL. I think a lot of the knowledge we tend to just forget, some of it was presented this morning in control instrumentation; that is knowledge, too. And that is knowledge that must be supported equally.

Senator BOGGS. Do I understand that there are serious limitations to our abilities to measure specific pollutants but rather we are measuring pollutant equivalents? Is that what you were saying?

Dr. CASSELL. Yes, and the equivalents continually change. That is the problem.

So, a reading of sulfur dioxide coming off the instrument, the problem is we get fooled on the draft paper and like that number so that we read off. Even though we do tend to forget, that is not sulfur dioxide, on Monday on a cloudy day it measured a number and on Tuesday the same number and then the same number on two different days meant different things about the quality of that atmosphere.

Senator BOGGS. And the effect on it.

Dr. CASSELL. And the effect on it.

Senator BOGGS. Do I also understand that you are suggesting that considerable research is needed in the area of monitoring techniques?

Dr. CASSELL. Yes.

Senator BOGGS. Both in the lab and in the community?

Dr. CASSELL. Yes.

Senator BOGGS. Well, I certainly congratulate you on your studies, Doctor.

Senator Cooper, do you have any questions?

Senator COOPER. I arrived near the end of your testimony, Dr. Cassell, but I have read your statement. As I understand, you are saying, first, that it is terribly difficult to identify sulfur or, in fact, any one agent or substance as being noxious per se.

Dr. CASSELL. That is right. That is correct.

Senator COOPER. It may be that a combination of agents, or their combination with, particulates could make them noxious?

Dr. CASSELL. Yes.

Senator COOPER. Am I correct in saying that part of the approach you suggest would be to control to the extent feasible all emissions into the atmosphere—discharges containing gasses and particulates which either singly or in combination may later be shown to be noxious?

Dr. CASSELL. That is correct.

Senator COOPER. And that your approach is more toward limiting, as best we can, the total emission, rather than sulfur dioxide or any other single element?

Dr. CASSELL. That is absolutely correct.

Senator COOPER. I think you are the first witness to raise this question. I have not been here all the time, but I have read a good many statements of those who have testified. It has just been accepted in these hearings, it seems to me—and as an assumption almost before we heard testimony—that sulfur dioxide is the agent we are after, at least from the burning of coal.

Dr. CASSELL. Take a moment. We have a bad disease in science called fadism.

If you take an instrument, an instrument is meaured that develops sulfur dioxide, it will clearly show it to be present in the air. It may even show it to be very high; it may make it maybe an easy subject to work with and start work going. It seems to indicate that it is going to be productive.

Air pollution as a generality becomes important because of a disaster and research money starts to go. It does not go so easily to the man who says "I don't know" as it does to the man who says "I got a way."

Since the way was the thing that we already knew how to measure, we start a cycle going. It may well be that it is the oxides of nitrogen about which we know very little, but I think we have to protect ourselves as much against the difficulties of our sciences as against the difficulties of our atmosphere.

One of the diseases of our science is that it tends to go down the line like this and it tends to forget it has a responsibility, an ever-increasing responsibility to society, and it has to say, well, recognizing our weaknesses, what our strengths are and how can we hit a problem from our strength rather than from our weaknesses?

That is what I intended.

Senator COOPER. You do not agree, then, with the approach of Public Health Service?

Dr. CASSELL. No.

Senator COOPER. I didn't think so.

Dr. CASSELL. I really do, actually. If you read the document they put out very carefully, it says in the preface that sulfur dioxide probably does not act alone, that to produce its effects it must be in combination with other things. That is about the last time you hear that in that document and from then on it is a statement of levels of sulfur dioxide. That is fine, but a little note of caution gets left out.

So the answer is, I agree with what is really written, but I do not agree with the implications that have been made throughout the document and the use that is made of it.

Senator COOPER. It may be difficult to answer this question, but at the close of your testimony you mention the kind of legislation that could be written to meet the problem as you see it. Can you give us some practical examples of what you think should be required in legislation to this problem, as you have described it, rather than just directing remedies to one specific agent?

Dr. CASSELL. Well, I will preface my answer by saying I do say this, that I am going to say I think it is somewhat of an answer but I recognize that it is not as easy a one as putting down a level and then saying we must meet it.

It may be, I think, that the statement "feasible" and the statement "maximum technology capability" for a particular industry or for a process is something that can be determined by joint industrial and governmental cooperation because it is a constant revising thing.

If, for example, we are pressing for the maximum feasible and maximum technological capability, and that is what it says, that gives the Public Health Service something to do. It can go into an area and say this process is not controlled to the maximum degree feasible or within technological capability and here is the evidence. They cite either other plants or new process improvements that have been reported on.

Industry may say, "That is too expensive; we cannot meet that," or "That is so wasteful of our fuel resources in the low sulfur fuel thing that it is not feasible," but at least a dialog is set up between the two which makes them work closer toward it.

Secondly, it gives the academic institution something to go toward directly. They are trying to find something feasible and they are trying to improve technological capability. I mean research, no matter who does it, but again we have all got a focus point. This accepts the facts that we now accept that we must control air pollution and I think that that has been a major change in the past few years.

Accepting that we go to feasible and maximum technological capability which are points which have real technological meaning, they have real fuel, and so forth and so on. They are points to which we can argue.

Senator BOGGS. Thank you, Senator Cooper.

Senator Spong?

Senator SPONG. No; I have no questions. I am sorry I was late.

Senator BOGGS. Doctor, we thank you very much.

Dr. CASSELL. Thank you.

(Subsequently Dr. Cassell, at the request of Senator Boggs, submitted the following paper:)

First let me return to the disasters. In London in 1952, when there were over 4,000 excess deaths, the highest concentration of sulfur dioxide was 1.34 parts per million. In London in 1962 with fewer excess deaths there was a higher hourly concentration of sulfur dioxide (1.98 ppm) and 678 micrograms per cubic meter of sulfuric acid but considerably lower levels of soot than in 1952. An air pollution episode occurred in New York City in 1953 that appeared to be associated with increased mortality and was reported by Dr. Greenberg's group. The SO_2 readings varied from .47 parts per million to .86 parts per million during the episode. Several other periods of high air pollution in New York City point to the conclusion that there may be an immediate effect on mortality of high levels of sulfur dioxide. Readings in the neighborhood of 2.4 parts per million as an instantaneous reading with the highest 2 hour hourly average of 1.5 parts per million have been recorded during such episodes. However, New York City air has a considerable concentration of particulate matter or soot. Studies by Gore and Chadick in London during four periods of increased air pollution showed that there are significant rises in mortality when the sulfur dioxide goes above .4 parts per million and the smoke above 2,000 micrograms per cubic meter. Martin and Bradley show evidence that death increased significantly when smoke rose above 750 micrograms per cubic meter and sulfur dioxide above .25 parts per million. Notice that in every situation quoted above, both sulfur dioxide and particulate matter must be increased before a health effect is seen.

Levels of sulfur dioxide as high as those measured during pollution episodes have been measured at other times in New York City without any adverse effect on human health.

I would like now to turn to another line of evidence, that deriving from the numerous studies on chronic bronchitis.

Even rough perusal of the morbidity and mortality data shows that chronic bronchitis is more commonly found in large towns than in sparsely populated areas of Great Britain. It has been easy to obtain high correlations between the prevalence of chronic bronchitis and the usual sulfur dioxide concentrations of an area, but the association cannot be assumed to be cause and effect since many other factors are associated with elevated levels of sulfur dioxide. (It has required some elegant work by Dr. Winklestein to dissociate the effect of socioeconomic status from the effect of air pollution.)

When chronic bronchitis and other indices of respiratory diseases were studied in exactly the same manner in the United States as they were in Great Britain real differences were found. In general we do not have as much chronic obstructive ventilatory disease here as in England. Although U.S. standings vary somewhat depending upon whether clinical criteria or laboratory tests are used, chronic bronchitis is essentially less in this country than in London, or rural England. Therefore, despite varying levels of sulfur dioxide in the United States, the prevalence of chronic bronchitis and similar diseases does not vary significantly. In addition, the overwhelming factor associated with chronic bronchitis is cigarette smoking. It is extremely difficult, if not impossible, to dissociate the effect of tobacco in the production of chronic bronchitis in a way that will allow evidence that chronic bronchitis is caused by air pollution. In England studies have been done on the fluctuation in wellbeing of individuals with chronic bronchitis. In general, when smoke is above 300 micrograms per cubic meter and sulfur dioxide above .21 parts per million, deterioration in the health of the group has been seen to occur. Note again, that both smoke and sulfur dioxide must be elevated to produce this effect on health. Dr. Lawther and his group in England have studied the problem extensively and indeed, have used themselves as experimental animals for years. They too, have been able to find virtually no effect of sulfur dioxide on themselves or other volunteers when used alone. When in combination with smoke or sulfuric acid mist an effect can sometimes be demonstrated. C. M. Fletcher's group in London followed intercurrent illness over a 3 year period in an industrial group, the majority of whom had some evidence of chronic bronchitis. In their analysis, they were able to show that while the attack rate of intercurrent illness correlated equally well with the concentrations of both smoke (particulate matter) and SO_2, the prevalence rate of illness correlated significantly with smoke alone.

Thus far I have attempted to show in two areas, how in the production of illness or death during disasters, and the worsening of pre-existing lung disease, particulate matter as well as sulfur dioxide is required before a health effect is produced.

The research which has produced the weakest evidence for a health effect of air pollution has been that which has attempted to show initiation of disease or illness in otherwise normal individuals.

Elegant and refined studies have attempted to contrast the health of individuals who live in areas similar in all respects except air pollution. The study of Dr. Prindle and his group from the Public Health Service in New Florence and Seward, Pennsylvania, is notable. These two towns, very close to one another, represent an excellent setting for the natural experiment. Seward had 3.2 times the dust fall and 6.2 times the amount of sulfation, but only 1.4 (or almost equal) amounts of suspended particulate as did New Florence, Pennsylvania. Nine percent of the average hourly sulfur dioxide readings in Seward were greater than .3 parts per million with highest hourly means 2.9 parts per million and a highest peak value 4.7 parts per million. Numerous measures of pulmonary function and respiratory disease were employed. Briefly stated, it can be said that there were no gross differences in the pulmonary function or diseases between the two towns. I would like you to note that although sulfation was markedly greater in Seward than in New Florence, the amount of suspended particulate matter was almost the same.

As the final pieces of evidence indicating that the health effects of air pollution may represent a combined effect of more than one pollutant I would like to present some of our findings from the Cornell Family Illness Study which has been in progress since 1961 under the direction of Dr. James McCarroll.

The population studied consisted of 1,815 persons living within a half-square mile area of lower Manhattan chosen as a reasonable cross-section of New York

City residents. A daily record of the appearance of each of 21 symptoms of illness as well as much other health information was obtained for each individual by weekly interview. The average length of time each individual remained in the study was 46 weeks.

A monitoring station was placed in the center of the study area to supply appropriate air pollution and meteorologic data.

For the first analysis to be presented, two symptoms are examined, cough and eye symptoms. The presence of either symptom for each of 1,054 days of the study was determined by a positive answer to the question, "Did you have a cough?" and "Did you have itching, burning or tearing of your eyes?" This particular analysis was carried out on the 1,090 adults and represents 247,800 person-days of observations. We used, as indicators of air pollution in this and the other examples, sulfur dioxide as measured by the Davis meter and particulate density as measured by the AISI sampler and expressed in COH units. In these examples 24 hour averages were used.

Correlation coefficients between each symptom and each measure of pollution were calculated. Because the appearance of a symptom on a given day might well be related to levels of air pollution at some time in the past, cross-correlations were calculated with a time lag of 0 to 28 days.

The data has been plotted as a series of correlograms since it is difficult to determine small differences in a mass of correlation coefficients listed in tabular form. The length of time spanned by a particular analysis is determined by the length of the time lag being examined, since the statistical method required that a period of time must be examined that is at least 10 times greater than the lag involved. The data has been examined in various ways. First with lags of 0 to 28 days based on 3 successive one-year periods; second, the same lags based on the total period; third, with lags of 0 to 21 days based on overlapping six-month periods; and finally, with lags of 0 to 3 days based on successive one-month observation periods.

The first slide displays a frequency distribution of the occurrence of symptoms and the occurrence of the levels of air pollution and will give you an idea of the amount of symptoms in this population as well as the magnitude of our air pollution problems.

Slide 2 shows a typical correlogram and represents the correlation coefficients of cough against SO_2 as well as the autocorrelations of cough and, below, of SO_2.

Inspection of the correlograms revealed differences between the behavior of the symptoms, cough and eye irritation, and between the effect of the environmental influences represented by sulfur dioxide compared with those represented by particulate density.

The cross correlation between SO_2 and eye symptoms characteristically shows a drop between the value of the correlation coefficient for lag 0 (that is the symptoms and the pollutants on the same day) and a lag of 1 day. In contrast the cross correlation between sulfur dioxide and cough typically shows an increase in the correlation coefficient between lag 0 and lag 1.

A different pattern emerged when the cross correlations of the same symptoms with particulate density were examined; the correlation coefficients of cough against particulate showed a similar increase between values for lag 0 and lag 1; whereas cross correlations between particulate density and eye irritation show no consistent relationship. This seems to indicate that the environmental influences represented by SO_2 have an immediate effect in the production of eye symptoms; and that there is a delay in the production of cough. Similarly, particulate matter appears to make no contribution to the production of eye symptoms, but does appear to contribute to the production of cough. (These findings are consistent with clinical and other evidence.)

If the environmental influences represented by SO_2 were the sole cause of cough, then the correlation coefficients would approach unity. Although characteristically positive they do not approach one. If these environmental influences in no way contributed to cough, the relationship between the correlation coefficients on a lag of 0 days and a lag of 1 day would be random.

In fact, however, the relationship in the case of SO_2 and both cough and eye symptoms is strong.

For particulate density and eye irritation, however, the relationship between lag 0 and lag 1 values is random.

In the next slide are listed the actual numbers of increases and decreases for each cross correlation.

It would therefore appear from the use of time series analysis that whatever is represented by the measure of SO_2 is not the sole cause, but does contribute

to the presence of cought and eye irritation in this adult population. Similarly, whatever is represented by the particulate density determination is not the sole cause, but does appear to contribute to the presence of cough.

A more detailed discussion of the method and findings has been presented elsewhere.

The same data were analyzed concurrently in another manner as devised by Dr. Isabel Mountain of our group.

In separate analyses the values for both particulate matter and sulfur dioxide were divided evenly into 15 groups. The number of person-days (a person-day is each day a person answered either "yes" or "no" to a symptom, omitting indefinite or unknown answers) is then distributed over the the days represented by the same grouping of pollutant. Thus if a particular SO_2 level occurred on 2% of the days the person-days present during that time are assigned to that 2% grouping. The symptom prevalance (the prevalance is the ration of symptom-days to person-days) can then be distributed in the manner expected if prevalence is solely dependent on person-days. The observed distribution of symptom-days is then plotted. If the distribution of symptom-days is dependent upon the level of pollutant the curve will be different from the curve resulting if the distribution is not dependent upon the pollution level.

For example, the next slide shows the method using the pollutant particulate matter and the symptom "colds" in the population of adults.

The next slide shows a curve where no difference is observed. (The pollutant is particulate matter and the symptom is headache).

The next slide shows the pollutant particulate matter with the system "colds". As can be seen, the observed prevalence of symptoms is consistently higher at the higher levels of particulate matter.

The next slide shows the same symptoms with the pollutant sulfur dioxide. Again the observed prevalence of symptoms is higher than expected at the upper levels of pollutants.

For particulate matter and sulfur dioxide there is a higher prevalence of the symptom cough than expected at the higher levels of pollutant.

Therefore we conclude that there is a detectable association between the symptoms cough and "colds" and the pollutants designated sulfur dioxide and particulate matter. We do not feel that the designation sulfur dioxide means the gas sulfur dioxide and consequently we consistently say whatever is represented by the measurement of SO_2 and whatever is represented by the measurement of particulate matter.

Again we have shown the same symptom associated with more than one environmental factor and again the same symptom associated with a measurement of SO_2 and particulate matter.

I have presented material from three lines of research: the air pollution disasters, studies on chronic lung disease, and investigations into "normal" urban populations. It is hoped that sufficient evidence has been marshalled to strongly suggest to you that sulfur dioxide and particulate matter must both be present in urban air to produce the observed health effects.

The conclusion I have come to is that sulfur dioxide and particulate matter under certain conditions react together in the atmosphere and are then capable of producing an adverse effect on health. This conclusion can be drawn solely from the epidemiologic evidence but as you have heard today there is strong parallel supporting evidence from the laboratory.

Senator BOGGS. There are no more witnesses scheduled.

I will place in the record a letter that was sent to the subcommittee by Robert Mintz of the Harvard Conservation Club.

(The letter is as follows:)

THE HARVARD CONSERVATION CLUB,
HARVARD UNIVERSITY,
Cambridge, Mass., May 12, 1967.

Hon. EDMUND S. MUSKIE,
Chairman, U.S. Senate Subcommittee on Air and Water Pollution, Senate Office Building, Washington, D.C.

DEAR SENATOR MUSKIE: Since I have communicated to you in the past on the subject of air pollution, I want to be brief this time.

The New York Times on May 11 reported that "representatives of American industry" and the United States Chamber of Commerce expressed to your committee opposition to the setting up of national standards for industrial emissions.

calling instead for local, state, or regional control. I wish to emphasize to the committee one particularly impelling reason in favor of uniform national standards: they will remove the weapon that polluters have wielded so successfully over the helpless public wherever it has proposed local controls—the threat to move away and deprive the area of jobs, a tax base, and prosperity.

A rather shocking example, one which you will remember, is described in the Public Health Service's reprint of *Saturday Evening Post's* cover article of October 8, 1966. Pollution from a paper mill in the town of Lincoln, Maine, was so intense in 1958 that it produced nosebleeds in residents and dyed their houses coffee-brown overnight. "The town council didn't want to be too tough because the mill had hired four hundred people in town, and they'd hint they'd move." A uniform standard for emissions would invalidate this kind of excuse for ignoring the public welfare.

May I also ask you please to have your office send our Club copies of the committee's reports on this subject and on automotive air pollution when they are available?

Thank you.

Sincerely yours,

ROBERT MINTZ,
Chairman, Air Pollution Committee.

(The following letter was subsequently received by Senator Baker in response to a query. It was ordered placed in the record at this point.)

U.S. ATOMIC ENERGY COMMISSION,
Washington, D.C., June 14, 1967.

Hon. HOWARD H. BAKER, Jr.,
U.S. Senate.

DEAR SENATOR BAKER: This is in reply to your letter of May 19 requesting information on AEC regulations for use of radioactive tracers in identifying and measuring sources of air and water pollution, and on research being conducted in this area.

The Commission has issued specific licenses under its regulations to conduct tracer studies relating to pollution control wherein radioactive materials have in some cases been released into the environment. Such environmental studies are considered for licensing only on the basis of review and approval of specific experiments rather than for routine use. The Commission generally requires each applicant for a license to submit a safety analysis for each experiment which demonstrates, among other things, that there is a substantial public interest in information intended to be obtained in the study, that the experiment will be conducted without undue risk to public health and safety, and that exposure of any person to ionizing radiation will be minimized to the extent feasible and will be well within permissible limits.

Regarding specific environmental applications of radioactive tracers in the United States, Nuclear Science & Engineering Corporation conducted a study for Hyperion Engineers, at Los Angeles, in 1958. The objective was to determine the dispersion of sewage from a pipe extending into the ocean. Several curies of scandium-46 were injected into the sewage flow, and dilution and dispersion measured with radiation detectors. It was learned that the ocean currents did not return the sewage to the beaches.

Other countries have made greater use of radioactive tracers in the environment to measure and control sources of air and water pollution. We have requested the Isotopes Information Center at Oak Ridge National Laboratory to

prepare summary information from published reports regarding such uses. These data will be forwarded to you when available.

On the other hand, radioactive tracers have been widely used in the U.S. for pollution studies under carefully controlled in-plant conditions. These in-plant studies were designed to learn better ways to minimize waste effluents before they are discharged to the environment. It is emphasized that the radioisotopes were used under carefully controlled research conditions, and any radioactive residues were collected and given special disposal.

In the past few years, there has been considerable development of ultrasensitive analytical techniques involving such things as neutron activation analysis, X-ray fluorescence, etc. These have enabled scientists to apply modern methods and portable equipment for more accurately and conveniently determining the concentration of a wide variety of environmental pollutants. Activation analysis, for example, permits the use in some cases of inert tracers to follow the course of a particular contaminant without having to add radioactivity to the biosphere. In other techniques, reliable and intense sealed sources of alpha, beta and gamma radiation are incorporated into field instruments wherein the degree of attenuation, scattering, or emission of radiation is a measure of the properties of the medium. In these applications, no radioactive material is released into the biosphere.

A new program for investigating the feasibility of using stable isotopes to diagnose sulfur dioxide was recently started at Brookhaven National Laboratory, at Upton, New York. The objective is to determine the sources, quantities, and meteorological distribution of SO_2 emitted to the atmosphere from stacks of fuel-burning plants. The project was initiated as a result of mutual interest by the AEC and the Bituminous Coal Research, Inc., of Pittsburgh, a research affiliate of the National Coal Association.

The BNL program calls for tagging stack emitted SO_2 with the stable isotopes sulfur-32 and -34. The ratio of S-32 over S-34 content from air samples collected at various locations around the selected emission points will be determined with mass spectrometers. Samples taken and analyzed before and after tagging, under various meteorological conditions could yield qualitative and quantitative dispersion information.

A more straightforward and reliable way to make these SO_2 measurements is through the use of radioactive sulfur-35. It is possible that a very limited use of this radioactive tracer may be undertaken on-site at BNL. At the moment, there are no plans to use the radioactive tracer in metropolitan areas.

If we can be of further help on this matter, please let us know.

Cordially,

GLENN T. SEABORG, *Chairman.*

Senator BOGGS. On behalf of the committee I extend my thanks to all who have attended faithfully. I especially want to thank those of you who have come to give us the benefit of your knowledge in this field. It is a particularly vexatious subject and one that will require a great deal of thought in arriving at a solution. The record will be kept open for additional statements. The staff will insert any received in the appropriate place so that continuity of subject material will be followed.

I thank you again. The subcommittee is adjourned.

(Whereupon, at 12 noon the subcommittee adjourned.)

INDEX

(Pp. 1–746 appear in pt. 1; pp. 747–1116 appear in pt. 2; pp. 1117–2229 appear in pt. 3; and pp. 2231–2683 appear in pt. 4)

STATEMENTS

Page

Adamson, John F., vice president, automotive engineering and research, American Motors Corp. 472

Andreas, Perry W., president, National Portland Cement Co., White Plains, N.Y.: Letter dated May 27, 1967 2198

Asrael, Stanley J., president, National Federation of Independent Scrap Yard Dealers, Inc. 2223

Avila, Charles F., president-elect, Edison Electric Institute; chairman, Edison Electric Institute Division; and executive committee chairman of the board of Boston Edison Co., accompanied by T. T. Frankenberg, consulting mechanical engineer for the American Electric Power Co.; and Maynard E. Smith, leader of the Meteorological Group, Brookhaven National Laboratory 2544

Babson, Frederick A., president, Metropolitan Washington Council of Governments: Letter dated April 24, 1967 1446

Barkelew, Mrs. Harry, president, Barkelew Manufacturing Co., Alhambra, Calif. 353

Barr, Harry F., vice president, engineering, General Motors Corp. 512

Baxter, Forrest V., president, Automotive Prototype Research, Inc., of California: Letter dated February 23, 1967 553

Bayh, Hon. Birch E., a U.S. Senator from the State of Indiana 1998

Bennett, Dr. Ivan L., Jr., Deputy Director, Office of Science and Technology, Executive Office of the President 788

Bergren, Orville V., Illinois Manufacturers' Association, Chicago, Ill. 2166

Bermingham, John R., a senator from the Colorado State Legislature 855

Biemiller, Andrew J., director, Department of Legislation, American Federation of Labor and Congress of Industrial Organizations 1664

Blasingame, Dr. F. J. L., American Medical Association, Chicago, Ill.: Letter dated May 15, 1967 2171

Blomquist, Dr. Edward T., Associate Director for Standards and Criteria Development Programs, National Center for Air Pollution Control, Public Health Service, U.S. Department of Health, Education, and Welfare, accompanied by Dr. John T. Middleton, Director, National Center for Air Pollution Control; Thomas F. Williams, Chief, Office of Legislative and Public Affairs; and Dr. John H. Ludwig, Associate Director for Control Technology Research and Development, National Center for Air Pollution Control 2232

Bloomfield, Bernard D., assistant chief, Division of Occupational Health, Michigan Department of Public Health: Letter dated April 12, 1967 1737

Bogan, B. W., vice president of engineering, Chrysler Corp. 408

Bosco, Neal, Weather Engineering, Inc., Denver, Colo.: Letters dated February 16 and 20, 1967 944

Boyd, James, president, Copper Range Co., New York, N.Y. 2174

Boyle, W. A., president, United Mine Workers of America, presented by Edward Carey, general counsel 2021

Brandt, Allen D., manager, Industrial Health Engineering Division, Industrial and Public Relations Department, Bethlehem Steel Corp. 2383

Burnett, Coy, president, Monolith Portland Cement Co., Los Angeles, Calif.: Letter dated May 22, 1967 2199

Burt, Robert E., director, Air and Water Resources Department, California Manufacturers Association 2169

Cadle, Dr. Richard D., head, Chemistry and Microphysics Department, National Center for Atmospheric Research, Boulder, Colo. 899

Page
Cairns, Donald F., president, Industrial Waste Control Council 1007
Callahan, Joseph M., engineering editor, Automotive News, accompanied by Jack Walsh, associate editor 542
Coplan, John, General Motors research laboratories 533
Carberry, Peter S., executive vice president, Independent Garage Owners of California, Inc 351
Cassell, Dr. Eric J., associate professor of community medicine and associate professor of medicine, Mount Sinai School of Medicine, New York, N.Y 2668
Clapper, Louis S., chief, conservation education, National Wildlife Federation 1751
Clark, Hon. Joseph S., a U.S. Senator from the State of Pennsylvania 1334
Commoner, Dr. Barry, chairman, Department of Botany, and director, Center for the Biology of Natural Systems, Washington University 978
Coons, Joseph D., consulting engineer, American Mining Congress 2178
Coston, Dean, Deputy Under Secretary of Health, Education, and Welfare, accompanied by Sidney Edelman, Office of the General Counsel 105
Cramer, Robert S., staff specialist, air and water conservation, Standard Oil Co. of California, representing the National Association of Manufacturers, accompanied by Daniel W. Cannon 2163
Daley, Hon. Richard J., mayor, Chicago, Ill., in behalf of the U.S. Conference of Mayors, accompanied by William J. Stanley, director, Chicago Department of Air Polution Control; and Robert Walter, conference staff 1895
Dealaman, Mrs. Doris W., chosen freeholder, National Association of Counties, accompanied by Mrs. Aliceann Fritschler, director of research, and C. D. Ward, general counsel 1353
Deem, R. Riley, R. R. Deem, consulting engineers, Indian Hills, Colo.: Letter dated February 10, 1967 945
Dempsey, Hon. John, Governor of Connecticut, on behalf of the National Governors' Conference, accompanied by Charles F. Schwan, Jr., director, Washington office, Council of State Governments, and Charles A. Byrley, director, National Governors' Conference 1468
Djerejian, Robert A., RA, AIA, vice chairman, Committee on the Natural Environment, New York Chapter, American Institute of Architects, accompanied by Olindo Grossi, dean, School of Architecture, director of environmental research, Pratt Institute, New York 1667
Doherty, James, legislative representative, accompanied by George Taylor, staff economist, Department of Legislation, AFL–CIO 1661
Dorn, Warren, supervisor, board of supervisors, County of Los Angeles, State of California 11
Douglass, Irvin B., professor, Department of Chemistry, University of Maine 1845
Dunn, Stephen F., president, National Coal Association 2017
Eckhardt, Hon. Robert C., a Representative in Congress from the State of Texas 1741
Edelman, Edmund D., councilman, Fifth District, City Council, Los Angeles, Calif 332
Ellis, Clyde T., general manager, National Rural Electric Cooperative Association: Letter dated March 13, 1967 1445
Fisher, Harold W., director and vice president, Standard Oil Co. (New Jersey), accompanied by Dr. Neil V. Hakala, executive vice president, Esso Research & Engineering Co., and Dr. Norman Alpert, Esso Research & Engineering Co 264
Fitzgerald, Bernard M., executive secretary, American Coke and Coal Chemicals Institute, Washington, D.C 2133
Fixman, Ben, president, Diversified Metals Corp 2542
Frankenberg, T. T., consulting mechanical engineer, American Electric Power Co 2548
Friedman, Don, a representative from the Colorado State Legislature 850
Fritts, Stewart S., operations consultant, Lone Star Cement Corp 2200
Fuller, Louis J., air pollution control officer, Los Angeles County, Calif 216
Gambs, Gerard C., assistant to vice president, chemicals, Consolidation Coal Co., accompanied by Ernest W. Anderson, advertising manager 2649

Page

Gammelgard, P. N., vice president, conservation and manufacturing, American Petroleum Institute, accompanied by Paul Bermingham, chairman, Committee on Laws and Regulations for Air and Water Conservation 2001
Gardner, Hon. John W., Secretary of Health, Education, and Welfare, accompanied by Ralph Huitt, Assistant Secretary for Legislation; Dean Coston, Deputy Under Secretary of Health, Education, and Welfare; William H. Stewart, M.D., Surgeon General; Vernon MacKenzie, Deputy Director, Bureau of Disease Prevention and Environmental Control; and John T. Grupenhoff, special assistant to Assistant Secretary for Legislation 759
Garvey, James R., president and director of research, Bituminous Coal Research, Inc., Monroeville, Pa 2407
Gehm, Dr. Harry W., technical director, National Council for Stream Improvement of the Pulp, Paper & Paperboard Industries, accompanied by Ernest J. Bolduc, Jr., executive secretary 2361
Goldsmith, S. L., executive vice president, Aluminum Association 2149
Grant, Eric P., executive director, Motor Vehicle Pollution Control Board, State of California 118
Green, Lewis C., chairman, Missouri Air Conservation Commission 991
Griswold, S. Smith, Associate Director for Abatement and Control, Public Health Service, Department of Health, Education, and Welfare, accompanied by Dr. Edward T. Blomquist, Associate Director for Standards and Criteria Development; and Dr. John H. Ludwig, Associate Director for Control Technology Research, and Development, National Center for Air Pollution Control 1309
Hahn, Kenneth, supervisor, Board of Supervisors, County of Los Angeles, State of California 148
Halsted, Donald M., Jr., president, Atlantic Cement Co., Inc., New York, N.Y.: Letter dated May 25, 1967 2200
Hardesty, C. Howard, Jr., executive vice president, Consolidation Coal Co 2038
Harrison, John S., executive vice president, Aluminum Co. of America, Pittsburgh, Pa., accompanied by Frank L. Seamans 2134
Hart, Hon. Philip A., a U.S. Senator from the State of Michigan: Letter dated February 18, 1967 392
Hartke, Hon. Vance, a U.S. Senator from the State of Indiana 1351
Hartman, W. V., vice president, Peabody Coal Co 2026
Havenner, Joseph E., executive vice president, Automobile Club of Southern California 292
Hibbard, Dr. Walter R., Jr., Director, Bureau of Mines, Department of the Interior, accompanied by Harry C. Allen, Jr 2456
Holloman, J. Herbert, Acting Under Secretary of Commerce, accompanied by Dr. Robert M. White, Administrator; Donald Pack, Acting Director, Air Resources Laboratory; and Robert Ellert, senior staff attorney, Environmental Science Services Administration 797
Honey, David C , Pacific Western Industries, Inc., Los Angeles, Calif.: Letter dated May 24, 1967 2199
Hutchins, Curtis, chairman, Dead River Co., representing the U.S. Chamber of Commerce, accompanied by Dr. Loren V. Foreman, vice president, Scott Paper Co.; and James Watt, staff executive, Natural Resources Committee 2154
Intemann, H. K., Union Carbide Corp.: Letter dated May 17, 1967 1886, 2606
Iverson, Clair H., Colorado Department of Health 911
Jonakin, James, assistant manager, Kreisinger Development Laboratory, Combustion Engineering, Inc., Windsor, Conn 2473
Julson, J. O., Air and Water Resources Committee, American Paper Institute, accompanied by George Boyd, counsel 1826
Kester, Bruce E., director of research, Missouri Portland Cement Co., representing Cement Advisory Committee, American Mining Congress, accompanied by Jack Gilliland, director of quality control, Ideal Cement Co 2617
Kuchel, Hon. Thomas H., a U.S. Senator from the State of California 8
Lenher, Samuel, E. I. du Pont de Nemours & Co., Inc.: Letter dated May 24, 1967 1795
Lieberman, Calvin, president, Ace Steel Baling, Inc., Toledo, Ohio, representing the Institute of Scrap Iron & Steel, Inc 2217
Lodge, Dr. James P., Jr., staff chemist, National Center for Atmospheric Research, Boulder, Colo 904

Page

Long, Hon. Edward V., a U.S. Senator from the State of Missouri 950, 2231
Low, Robert A., councilman, Fourth District, Manhattan, New York, N.Y 1480
Ludwig, Dr. John H., Associate Director for Control Technology Development Program, National Center for Air Pollution Control, Public Health Service 2265
McCabe, Louis C., president, Resources Research, Inc., subsidiary of Hazleton Laboratories, Inc., and chairman of the board, Hazleton Laboratories, Inc., accompanied by John S. Lagarias, executive vice president, Resources Research, Inc.; and Harold N. MacFarland, vice president, Resources Research, Inc., and director, Inhalation Division, Hazleton Laboratories, Inc 2659
MacNider, Jack, president, Northwestern States Portland Cement Co., Mason City, Iowa: Letter dated May 29, 1967 2199
Madar, Olga, executive board member and director, United Automobile Workers, on behalf of Walter Reuther, president, United Automobile Workers 535
Maga, John, chief, Bureau of Air Sanitation, Department of Public Health, State of California 318
Mann, Thomas, president, Automobile Manufacturers Association; accompanied by Herbert L. Misch, vice president of engineering, Ford Motor Co.; B. W. Bogan, vice president and director of engineering, Chrysler Corp.; Harry F. Barr, vice president of engineering, General Motors Corp.; and John F. Adamson, vice president of automotive engineering and research, American Motors Corp 393, 1761
Martin, Roblee B., president, Dundee Cement Co., Dundee, Mich 2198
Mattison, Dr. Berwyn F., executive director, American Public Health Association 1734
Mercker, A. E., executive secretary, Vegetable Growers Association of America 2227
Meredith, H. H., Jr., coordinator of air and water conservation, Humble Oil & Refining Co., representing the American Petroleum Institute, accompanied by C. W. Lubbock, member of the task force, American Petroleum Institute, Houston, Tex 2487
Metcalf, Hon. Lee, a U.S. Senator from the State of Montana 1891
Metzler, Dwight F., American Society of Civil Engineers 1731
Middleton, John T., Director, National Center for Air Pollution Control, Public Health Service; accompanied by Dr. Edward T. Blomquist, Associate Director for Standards and Criteria Development Programs; Thomas F. Williams, Chief, Office of Legislative and Public Affairs, and Dr. John H. Ludwig, Associate Director, Control Technology Research and Development 1149, 2513
Mighdoll, M. J., National Association of Secondary Material Industries 2151
Miller, L. E., president, Santee Portland Cement Corp., Holly Hill, S.C.: Letter dated May 22, 1967 2200
Mintz, Robert, chairman, Air Pollution Committee, the Harvard Conservation club, Harvard University, Cambridge, Mass.: Letter dated May 12, 1967 2681
Misch, Herbert L., vice president, engineering, Ford Motor Co 483
Monroe, George B., president, Phelps Dodge Corp 2214
Moody, Joseph E., president, National Coal Policy Conference, Inc 2016
Morse, Hon. Wayne, a U.S. Senator from the State of Oregon 1331
Moss, Hon. Frank E., a U.S. Senator from the State of Utah 1449
Murphy, Hon. George, a U.S. Senator from the State of California 2
Nelsen, K. W., director, Department of Hygiene and Agricultural Research, American Smelting & Refining Co 2215
O'Fallon, John E., director of building inspection, Denver, Colo., appearing for the National League of Cities 876, 1435
O'Meara, John, senior vice president, Banner Iron Works, St. Louis, Mo.: Letter dated May 8, 1967 2225
Outman, Boyd J., executive secretary, Association of American Railroad Car Dismantlers, Chicago, Ill.: Letter dated May 10, 1967 2226
Overton, J. Allen, Jr., executive vice president, American Mining Congress 2172
Palomba, Joseph, Jr., chief, Air Pollution Section, Colorado State Department of Health 861
Penfold, Joseph W., conservation director, Izaak Walton League of America 1757

Page
Pollock, W. A., Wisconsin Electric Power Co.: Letter dated April 18, 1967 2592
Price, Hon. Melvin, a Representative in Congress from the State of Illinois 1893
Randolph, Hon. Jennings, a U.S. Senator from the State of West Virginia 5, 1329
Rands, Betty H., president, American Association of University Women: Letter dated February 4, 1967 1116
Reed, Sherman K., director, Central Research Department, FMC Corp., accompanied by Norris J. Brunsvold, FMC Corp., Princeton, N.J 2504
Reseigh, Thurlow C., planning and research engineer, Colorado Department of Highways 937
Ribicoff, Hon. Abraham A., a U.S. Senator from the State of Connecticut 2512
Roberts, Dr. Walter Orr, Director, National Center for Atmospheric Research, Boulder, Colo 888
Saunders, Stuart T., chairman of the board, Pennsylvania Railroad Co 2128
Schuck, Edward A., Statewide Air Pollution Research Center, University of California, Riverside, Calif 326
Schueneman, Jean J., Chief, control development program, National Center for Air Pollution Control, Public Health Service, Cincinnati, Ohio 951
Seaborg, Glenn T., Chairman, U.S. Atomic Energy Commission 2682
Smathers, Hon. George A., a U.S. Senator from the State of Florida 1348
Smith, Maynard E., leader of the Meteorological Group, Brookhaven National Laboratory 2566
Smith, Spencer, secretary, Citizens Committee on Natural Resources 1747
Snyder, Andrew J., president, Century Cement Manufacturing Co., Inc., Rosendale, N.Y.: Letter Dated May 25, 1967 2199
Sporn, Philip, retired president, American Electric Power Co., Inc., and vice chairman, National Coal Policy Conference, Inc 2043
Stern, Arthur C., Assistant Director, National Center for Air Pollution Control, Public Health Service, accompanied by Robert A. McCormick, Chief, meteorology program 830
Sterner, Dr. James, chairman, National Air Conservation Commission 1733
Stewart, Hon. William H., Surgeon General of the United States, Public Health Service, U.S. Department of Health, Education, and Welfare 1118
Stites, Dr. Joseph C., Jr., enterprise manager, air pollution control, commercial development department of the Inorganic Chemicals Division, Monsanto Co., St. Louis, Mo., accompanied by Cecil Underwood, Washington, D.C., regional vice president, Monsanto Co.; Ralph F. Bovier, Johnstown, Pa., vice president-technical, Pennsylvania Electric Co.; and John G. Miller, Reading, Pa., chief engineer, Metropolitan Edison Co 2467
Stockman, Robert L., Washington State Department of Health, Seattle, Wash., appearing for Hon. Daniel J. Evans, Governor of Washington 1672
Stone, G. N., and A. J. Clarke, Central Electricity Generating Board, London, England 2103
Sullivan, Harold W., commissioner, California Highway Patrol, accompanied by Eugene Beck 284
Swan, David, vice president-technology, Kennecott Copper Corp., New York, N.Y 2177
Symington, Hon. Stuart, a U.S. Senator from the State of Missouri: Letter dated March 23, 1967 949
Taylor, W. R., manager of engineering, Diamond Alkali Co., Cleveland, Ohio 2227
Tucker, Fred, manager of pollution control and services, National Steel Corp., accompanied by K. G. Jackson, corporation counsel 1797
Verity, William, president, Armco Steel Corp.: Letter dated May 2, 1967 1825
Warren, John G., vice chairman, Illinois Air Pollution Control Board 1001
Weber, Herbert J., director of safety, hygiene and air pollution controls, American Foundrymen's Society, Des Plaines, Ill 2213
Wegman, Leonard S., partner, Leonard S. Wegman Co., representing Consulting Engineers Council of America 2611
Wessells, Vincent E., vice president of research, Ideal Cement Co., Denver, Colo 2190
White, Dr. Robert M., Administrator, Environmental Science Services Administration, Department of Commerce 803
Wilkenfeld, Jerome, Manufacturing Chemists Association, accompanied by George T. Scriba 1783, 2594

Page

Williams, Spencer, administrator, Department of Health and Welfare, State of California 104
Wilson, Earl L., president, Industrial Gas Cleaning Institute, and manager, Industrial Gas Cleaning Department, Koppers Co., Inc.; accompanied by Charles A. Gallaer, chief engineer, Buell Engineering Co., and member, Engineering Standards Committee, Industrial Gas Cleaning Institute; and Herbert R. Herington, executive secretary, Industrial Gas Cleaning Institute 2629

ADDITIONAL INFORMATION SUBMITTED FOR THE RECORD

Air pollution and the public health 2203
Air pollution control act of the State of Colorado 862
Air pollution control district, County of Los Angeles, rules and regulations 21
Air pollution from aircraft in Los Angeles County—A report of the engineering division, December 1965 248
Air pollution—Some meteorological aspects, by R. A. McCormick and Robert A. Taft 816
Amendments Nos. 154, 174, 175, and 181 to S. 780 1456
Analysis of Stone & Clarke paper presented to the subcommittee on May 10, 1967 2283
AQ & ED Branch, NASN Section, commuter exposure to carbon monoxide 2263
Automobile Club of Southern California—Compulsory periodic motor vehicle inspection 300
Blueprint for Cleaner Air—Council of the city of New York 1569
British experience with tall stacks for air pollution control on large fossil-fueled powerplants 2107
Chapter 17 of the Municipal Code of Chicago relating to air pollution control 1901
Chicago's program with the steel industry 1988
Chronological list of General Motors contributions to air pollution studies 739
City of Chicago Air Quality, Telemetering System, by Samuel G. Booras 1951
Clean air program, by Industrial Waste Control Council of Illinois 1010
Combustion chamber surface area, a key to exhaust hydrocarbons 724
Commonwealth of Pennsylvania, Department of Health, Air pollution Commission, ambient air quality criteria 2396
Community Action Guide for Public Officials: Air pollution control 1360
Control of dust emission—combustion for indirect heat exchangers 2419
Current status and future prospects—Pulpmill air pollution control 1834
Current status report—State and local air pollution control programs, May 1967 1160
Design and development of the General Motors air injection reactor system 643
East-West Gateway Coordinating Council, comparison of interstate air pollution with Industrial Waste Control Council, proposal for a clean air program, city of St. Louis bill 134, and county of St. Louis bill 286 1081
Effect of fuel antiknock compounds and deposits on exhaust emissions, by J. C. Gagliardi, Ford Motor Co 487
Effectiveness of exhaust controls in public use 134
Effectiveness of exhaust controls on 1966 vehicles by the State of California Motor Vehicle Pollution Control Board, August 10, 1965 275
Electrovair—A battery electric car 769
Electrovan—A fuel cell powered vehicle 691
Evidence concerning the effects of sulfur dioxide 2531
Exhaust emission control by Chrysler—The cleaner air package 411
Factual record of correspondence between Kenneth Hahn, Los Angeles County supervisor, and the presidents of General Motors, Ford, and Chrysler regarding the automobile industry's obligation to meet it's rightful responsibility in controlling air pollution from automobiles 155
Financial assistance for the construction of air pollution control facilites 1839
High performance AC electric drive system 706
High stacks for the diffusion of sulfur dioxide and other gases emitted by electric powerplants 2557
Hydrocarbon control as of February 1, 1967, in California 121
Hydrogen-oxygen thin electrode fuel cell module 717
Ice nuclei from automobile exhaust and iodine vapor, by Vincent J. Schaefer 842

Page
Illinois-Indiana air pollution control compact 1820
Implications of the interstate air pollution study, St. Louis regional area, for regional programs in air pollution control, by J. J. Scheuneman and J. D. Williams 958
Interstate air pollution effects network 1303
Letter of April 21, 1967, from Senator Muskie to Dr. John Middleton 2346
Letter of March 31, 1967, from Senator Muskie to Dr. John Middleton 2333
Listing of the 20 areas with the most severe air pollution problems among the 65 standard metropolitan statistical areas having an industrial population of 40,000 or more 2031
Local laws of the city of New York for the year 1966 1482
Marketing fly ash—U.S. and European programs 2653
Mechanical collectors 2640
Meteorology of air pollution—The need to preserve our air resources challenges our understanding of the atmosphere's capacities, by Donald H. Pack 822
Mid-Atlantic States air pollution control compact 1624
Mid-West Coal Producers Institute, Inc., statement on emissions of sulfur dioxide in the interstate air pollution study area 1111
Mixing depths, wind speeds, and air pollution potential for selected locations in the United States 2287
Motor vehicle air pollution bills in the State legislatures—Status report, February 16, 1967 395
Motor Vehicle Pollution Control Board, California 126
1967 Ohio, West Virginia Legislatures to get air pollution control compact 768
Ohio-West Virginia air pollution control compact 1814
Pioneering experience with high stacks on the OVEC and American Electric Power Systems 2550
Planning and implementing Chicago's package programs 1963
Potentialities of emission reduction by design of induction systems, by Earl Bartholomew 917
Present approach to control of motor vehicle exhaust emissions, by B. W. Bogan, Chrysler Corp 453
Prevention, control, and abatement of air pollution from Federal Government activities: Performance standards and techniques of measurement 1887
Recommendation for conforming and consolidating the rules and regulations of the five southern California air pollution control districts, February 23, 1966, by Louis J. Fuller 336
Reduction of ambient air concentrations of pollutants by dispersion from high stacks 2567
Report on Commonwealth Edison Co.'s air pollution control program, to the city of Chicago's Department of Air Pollution Control 1943
Resolution of the Board of Supervisors, County of Los Angeles, Calif 215
Revised proposal for air pollution control regulations for the interstate St. Louis metropolitan area 1086
Right of entry provisions in laws of States represented by members of the Senate Subcommittee on Air and Water Pollution 773
Ruberoid promises air pollution curb 1434
Senator Randolph discusses the need for parity in Government research financing of nuclear power investigation on the one hand and coal on the other 2454
Simplified control system for nitrogen oxides in vehicle exhaust, by Arco Chemical Co. (a division of Atlantic Richfield) 369
SO_2 control project list 2328
Some chemical aspects of kraft odor control, by Irwin B. Douglass 1847
Special report to Mayor John V. Lindsay 1993
Statement of governmental agencies concerned with air pollution control in the Metropolitan St. Louis area 963
Status of current technology in the control of emissions to the atmosphere 2274
Status report—Performance of emission control systems, by Eric P. Grant 143
Sulfur content of U.S. coals 2053
Summary of air pollution control program grants by States 2347
Summary of air sampling stations—1967 2240
Summary of Conference on Interstate Air Pollution in the Shoreham, Vt.-Ticonderoga, N.Y., area 1310
Summary of continuous monitoring—1966 2246

Page
Summary of funds allocated for SO_2 control projects, fiscal year 1967 2327
Summary of I.G.C.I. research and development information survey 2639
Summary of 1964–65 air quality measurements 1298
Text of telegraphic message from U.S. Senator Jennings Randolph, chairman, Senate Committee on Public Works, to Fred E. Tucker, chairman, Ohio-West Virginia Industry Committee on Air Pollution Abatement, dated December 19, 1966 768
The coal gasifier/gas turbine method of electric power generation 2451
To master our atmospheric environment, by Dr. Walter Orr Roberts 894
Union Carbide opens world's largest phenol unit near Bound Brook, N.J 1434
Use of particulate collection by industry 2637
Utah State Department of Health—Developments in the field of air pollution subsequent to 1962 1454
Vehicle exhaust control—Problems and solutions, by C. M. Heinen, Chrysler Corp 425
Vehicle fuel cell system 661
Washington Clean Air Act—1967 1674
What factors determine the optimum size area for an air pollution control program, by Morris Neiburger 842

ORGANIZATIONS

Ace Steel Baling, Inc., Toledo, Ohio 2217
Air Pollution Control District, Los Angeles County, Calif 216
Aluminum Association 2149
Aluminum Co. of America, Pittsburgh, Pa 2134
American Association of University Women 1116
American Coke and Coal Chemicals Institute, Washington, D.C 2133
American Electric Power Co 2544, 2548
American Federation of Labor & Congress of Industrial Organizations 1661, 1664
American Foundrymen's Society, Des Plaines, Ill 2213
American Institute of Architects 1667
American Medical Association 2171
American Mining Congress 2172, 2178
American Motors Corp 472
American Paper Institute 1826
American Petroleum Institute 2001, 2487
American Public Health Association 1734
American Smelting & Refining Co 2215
American Society of Civil Engineers 1731
Armco Steel Corp., Middletown, Ohio 1825
Association of American Railroad Car Dismantlers, Chicago, Ill 2226
Atlantic Cement Co., Inc., New York, N.Y 2200
Augustana College, Rock Island, Ill 553
Automobile Club of Southern California 292
Automobile Manufacturers Association 393, 1761
Automotive News 542
Automotive Prototype Research, Inc. of California 553
Banner Iron Works, St. Louis, Mo 2225
Barkelew Manufacturing Co., Alhambra, Calif 353
Bethlehem Steel Corp 2383
Bituminous Coal Research, Inc., Monroeville, Pa 2407
Brookhaven National Laboratory 2544, 2566
California Department of Public Health 318
California Highway Patrol 284
California Manufacturers Association 2169
California Motor Vehicle Pollution Control Board 118
Cement Advisory Committee, American Mining Congress 2617
Central Electricity Generating Board, London, England 2103
Century Cement Manufacturing Co., Inc., Rosendale, N.Y 2199
Chicago Department of Air Pollution Control 1895
Chrysler Corp 408
Chrysler Research Center, Detroit, Mich 555
Citizens Committee on Natural Resources 1747
City Council, Los Angeles, Calif 332
Colorado Department of Highways 937

Page
Colorado State Department of Health 861, 911
Colorado State Legislature 850, 855
Combustion Engineering, Inc., Windsor, Conn 2473
Consolidation Coal Co 2038, 2200, 2649
Consulting Engineers Council of America 2606
Copper Range Co., New York, N.Y 2174
Correspondence between Kenneth Hahn, Los Angeles County supervisor, and General Motors, Ford, and Chrysler 155
Council of State Governments 1468
Denver Building Department, City and County of Denver, Colo 876
Department of Commerce 797
Department of Health and Welfare, California 104
Department of Health, Education, and Welfare 105, 759, 1118, 1309, 2232, 2265, 2513
Department of the Interior 2456
Diamond Alkali Co., Cleveland, Ohio 2227
Diversified Metals Corp 2542
Dundee Cement Co., Dundee, Mich 2198
Edison Electric Institute 2544
E. I. du Pont de Nemours & Co., Inc., Wilmington, Del 1795
Environmental Science Services Administration, Department of Commerce 803
Esso Research & Engineering Co 264
Ethyl Corp., Detroit Mich 917
FMC Corp., Princeton, N.J 2504
Foote Mineral Co., Exton, Pa 2175
Ford Motor Co 483
Ford Service Research Center, Detroit, Mich 589
General Motors Corp 512
General Motors Research Laboratories 533
General Motors research plant, Detroit, Mich 619
General Portland Cement Co 2176
Harvard University, Cambridge, Mass 2681
Humble Oil & Refining Co., Houston, Tex 2487
Ideal Cement Co., Denver, Colo 2172, 2190
Illinois Air Pollution Control Board 1001
Illinois Manufacturers' Association, Chicago, Ill 2166
Independent Garage Owners of California, Inc., Los Angeles, Calif 351
Industrial Gas Cleaning Institute 2629
Industrial Waste Control Council 1007
Institute of Scrap Iron & Steel, Inc 2217
Izaak Walton League of America 1757
Kennecott Copper Corp., New York, N.Y 2177
Lone Star Cement Corp 2200
Los Angeles, Calif., Chamber of Commerce 352
Los Angeles County Air Pollution Control District 216
Los Angeles County, Calif., Board of Supervisors 11, 148
Manufacturing Chemists Association 1783, 2594
Metropolitan Edison Co 2467
Metropolitan Washington Council of Governments 1446
Michigan Department of Public Health 1737
Mid-West Coal Producers Institute, Inc 1111
Missouri Air Conservation Commission 991
Monol th Portland Cement Co., Los Angeles, Calif 2199
Monsanto Co., St. Louis, Mo 1110, 2467
Mount Sinai School of Medicine, New York, N.Y 2668
National Air Conservation Commission 1733
National Association of Counties 1353
National Association of Manufacturers 2163
National Association of Secondary Material Industries 2151
National Center for Air Pollution Control, Public Health Service 830, 951, 1149, 1309
National Center for Atmospheric Research, Boulder, Colo 888, 899, 904
National Coal Association 2017
National Coal Policy Conference, Inc 2016, 2043
National Council for Stream Improvement, Pulp, Paper & Paperboard Industries 2361

Page
National Federation of Independent Scrap Yard Dealers, Inc 2232
National Governors' Conference 1468
National League of Cities 1435
National Portland Cement Co., White Plains, N.Y 2198
National Rural Electric Cooperative Association 1445
National Steel Corp 1797
National Wildlife Federation 1751
New York State Legislature 1480
Northwestern States Portland Cement Co., Mason City, Iowa 2199
Office of Science and Technology, Executive Office of the President 788
Ohio-West Virginia Industry Committee on Air Pollution Abatement, Weirton, W. Va 768
Pacific Western Industries, Inc., Los Angeles, Calif 2199
Peabody Coal Co 2026
Pennsylvania Electric Co 2467
Pennsylvania Railroad Co 2128
Phelps Dodge Corp 2214
Pratt Institute, New York 1667
Resources Research, Inc., a subsidiary of Hazleton Laboratories, Inc 2659
R. R. Deem, consulting engineers, Indian Hills, Colo 945
Santee Portland Cement Corp., Holly Hill, S.C 2200
Scott Paper Co 2154
Standard Oil Co. (New Jersey) 264
Statewide Air Pollution Research Center, University of California, Riverside, Calif 326
Union Carbide Corp 1886, 2606
United Automobile Workers 535
United Mine Workers of America 2021
U.S. Atomic Energy Commission 2682
U.S. Chamber of Commerce 2154
U.S. Conference of Mayors 1895
University of Maine 1845
Utah Construction & Mining Co., San Francisco, Calif 2174
Vegetable Growers Association of America 2227
Washington State Department of Health 1672
Washington University, St. Louis, Mo 978
Weather Engineering, Inc., Denver Colo, 941
Western Electric Co., Inc 942
Wisconsin Electric Power Co 2592

○