DEFENSE PRODUCTION ACT PROGRESS REPORT—NO. 50

POTENTIAL SHORTAGES OF ORES, METALS, MINERALS, AND ENERGY RESOURCES

HEARING

BEFORE THE

JOINT COMMITTEE ON DEFENSE PRODUCTION

CONGRESS OF THE UNITED STATES

NINETY-SECOND CONGRESS

FIRST SESSION

ON

POTENTIAL SHORTAGES OF ORES, METALS, AND MINERALS, FUELS AND ENERGY RESOURCES, ESTIMATED FUTURE PRODUCTION AND CONSUMPTION, RECYCLING OF METALS, DEPENDENCE ON FOREIGN SOURCES, RECOMMENDATIONS FOR MEETING DEMAND, AND RELATED MATTERS

AUGUST 2, 1971

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POTENTIAL SHORTAGES OF ORES, METALS, MINERALS, AND ENERGY RESOURCES

MONDAY, AUGUST 2, 1971

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON DEFENSE PRODUCTION,
Washington, D.C.

The committee met, pursuant to call, at 10 a.m. in room 2222, Rayburn House Office Building, the Hon. Wright Patman (chairman) presiding.

Present: Representatives Patman (presiding), Barrett, Sullivan, Widnall, and Brown.

Also present: Harold J. Warren, clerk and counsel; Charles S. Brewton, general counsel; George T. Ault, professional staff; Cary H. Copeland, professional staff; and Joel Lumer, staff assistant.

Chairman PATMAN: The committee will please come to order.

I have a short statement that I would like to read. I think it gives some information that is vital.

I look upon this as one of the most important contemplated hearings in which I have ever engaged. It leads to the future of our country and whether or not we have the wherewithal to do what we should do.

I will read the statement.

The Defense Production Act was passed in 1950. As related to metals and minerals, this act provided incentives for the expansion of productive capacity and supply. The authority to purchase materials for the national stockpile existed at that time, but metals and minerals could not be found from either domestic sources or foreign sources for purchase. When the expansion programs authorized in the Defense Production Act became effective, materials became available for purchase by private industry and the national stockpile at market prices.

In the early 1950's an evaluation of the Nation's resources was being made by the Paley Commission. An evaluation was made of the probable demand for major minerals in the 1970's. The 1970's have arrived, and the Department of the Interior is now attempting to make an assessment of the raw material requirements of the United States for the future, extending to the year 2000. We have been reminded that the year 2000 extends no further into the future than World War II extends into the past.

The Joint Committee on Defense Production is interested in these forecasts for future years, and is also interested in the kinds of action which will be required to provide adequate supplies of raw materials to meet the requirements of the United States. In past years this country has been concerned primarily with defense requirements for raw materials, while recognizing the necessity for maintaining what has been referred to as "rock bottom civilian requirements." With increased dependence on foreign sources for metals and minerals, determinations should be made concerning the steps which must be taken to meet our future needs for raw materials. A question arises as to whether the programs of the past will meet the needs of the future.

We appear to be faced with diminishing domestic reserves of raw materials, lower grades of ore, potential shortages of fuel and energy, an increased dependence on foreign sources of supply, greater competition in purchasing metals and minerals in foreign markets, a reduction in training programs in colleges and graduate schools for highly qualified personnel for the minerals industry, estimates of continuing increases in population as well as increases in the gross national product, and greater per capita consumption of raw materials, while attempting to meet the challenges which relate to the environment in the mining and processing of raw materials. Yet, metals, and fuels and energy, are essential to the operation of our assembly lines and to our future growth.

This committee has expressed concern about the dependence of the United States on foreign sources for metals and minerals in recent annual reports. Figures have been requested from the Department of the Interior in a form which had not been published previously. The most recent annual report of this committee sets forth 16 strategic and critical materials for which the United States was dependent on foreign sources for 50 percent to 100 percent of 1969 consumption. In addition, the United States was dependent on one or two sources of foreign supply for a number of metals and minerals. As dependence on foreign sources increases, there is a tendency toward price increases, as has occurred in connection with the price of foreign oil in recent months.

Since 1950, there has been a high rate of economic growth and impacts of science and technology on materials demand. In recent years, the gross national product has increased at the rate of 3 percent to 3.5 percent and the Department of the Interior anticipates an increase of 4 percent for the remainder of the century.

It is reported that despite the apparent healthy state of many mineral industries and the increasing demand for their output, the rate of new discoveries and the development of reserves is declining for a wide range of minerals. Technology has not been forthcoming to lower costs and increase available supply from presently classified marginal and submarginal resources. The trend for a growing number of primary minerals is toward higher costs, a leveling off of domestic production, losses of traditional markets, recourse to substitutes, and increasing dependence on foreign sources of supply.

The Department of the Interior states that technology must be applied to broadening the recoverable portion of the resource base through development of new techniques of exploration and discovery for resources, lowering the cost of development of presently classified marginal and submarginal reserves, extending mineral supply through recycling, and maximizing the recovery and utilization of byproducts and coproducts.

It is estimated that the annual growth of total domestic demand for minerals will range from 3.4 to 5.5 percent for the remainder of the century. This is said to amount to a cumulative domestic demand of from $2 trillion to $2.9 trillion.

The Department of the Interior recently reported that in the last 30 years the United States has consumed more minerals than the entire world for all time before. Based on the forecasts for the year 2000 the total constant dollar value of demand for minerals in the Nation is expected to increase from three to five times the current level.

This committee is interested in making some assessment of the expansion programs and other actions which will be required to meet the raw material needs of the United States. It appears that the materials which will be available to the United States, including fuels and energy, will be dependent on our domestic reserves, the technology we employ in increasing and utilizing these reserves of raw materials, the availability of raw materials in foreign markets, the extent to which we are able to shift our emphasis toward the use of conservation practices and the recycling of materials, our ability to develop and utilize substitutes, and the success we achieve in finding solutions to environmental considerations.

We have with us today Hon. Hollis M. Dole, Assistant Secretary of the Interior for Mineral Resources.

Mr. Dole, if you will present all the people who are here who are interested in this and who are cooperating with us on this very valuable study it will be appreciated. Will you identify them for the record and state who they are. And if you don't want to go into all of it at length you can do that when you get the transcript.

STATEMENTS OF HON. HOLLIS M. DOLE, ASSISTANT SECRETARY OF THE INTERIOR FOR MINERAL RESOURCES; ACCOMPANIED BY DR. E. F. OSBORN, DIRECTOR OF THE BUREAU OF MINES, ACCOMPANIED BY DR. JOHN MORGAN, ASSISTANT DIRECTOR OF MINERAL POSITION ANALYSIS, AND DR. PAUL ZINNER, ASSISTANT DIRECTOR FOR PLANNING; H. L. MOFFETT, DIRECTOR, OFFICE OF MINERALS AND SOLID FUELS, ACCOMPANIED BY JOHN SHELTON; JOHN RICCA, ACTING DIRECTOR, OFFICE OF OIL AND GAS; W. A. RADLINSKI, ACTING DIRECTOR, U.S. GEOLOGICAL SURVEY, ACCOMPANIED BY WILLIAM PRINZ, ASSISTANT CHIEF GEOLOGIST, HAROLD KIRKEMO, CHIEF, OFFICE OF MINERALS EXPLORATION, AND REID STONE, OIL SHALE COORDINATOR; AND GEORGE FUMICH, JR., DIRECTOR, OFFICE OF COAL RESEARCH

Mr. Dole. Thank you, Mr. Chairman and members of the committee, it is indeed a pleasure to appear before you today to discuss the production and demand for metals and minerals in the United States, the extent of our dependency upon foreign sources, and steps being taken to improve our supply situation through improved technology and reclamation and recycling of materials.

I am accompanied this morning by members of my staff and representatives from the U.S. Bureau of Mines, U.S. Geological Survey, and the Offices of Oil and Gas and Coal Research. Statements will be presented to you during the course of these hearings by Dr. Osborn, Director of the U.S. Bureau of Mines, Mr. W. A. Radlinski, Acting Director, U.S. Geological Survey, and John Ricca, Acting Director, Office of Oil and Gas.

Chairman PATMAN. Mr. Widnall.

Mr. WIDNALL. Will the chairman yield to me at this point?

Chairman PATMAN. Certainly, sir.

Mr. WIDNALL. Mr. Chairman, I unfortunately have a conflict at this time. Secretary Romney is appearing before the housing committee directly below us. And I would like to leave at this time and then come back. I will be sure and read all the statements. And I am very happy that all of you are here this morning. I am sure you will make a very important contribution to the future of the United States.

Mr. DOLE. Thank you.

Chairman PATMAN. Thank you for coming up to the opening. And we will look forward to seeing you return when it is possible to do so.

Mrs. SULLIVAN. Mr. Chairman, may I interrupt you today. We had set before this hearing was set a review of negotiations that are going on right now between the Republic of Panama and the United States.

Chairman PATMAN. You were chairman of that committee about 14 years; weren't you?

Mrs. SULLIVAN. I was chairman of it for 14 years. And we are going to meet in our full committee to discuss these in executive session. So, I must be excused at 10:30 or 10:25.

Chairman PATMAN. Thank you, ma'am. It was very nice of you to come. And we understand that. It is awfully hard to have a committee meeting with so many other meetings. But we were determined to have the committee meeting and get started on the program we were expecting to develop throughout this session.

Thank you very much.

Go ahead, Mr. Dole.

Mr. DOLE. Mr. Chairman, the Department of the Interior considers these hearings to be of very great importance. And so, with your permission we have brought along with us some of our experts from the various offices and bureaus. Accompanying Mr. Radlinski, Acting Director of the Geological Survey, is Dr. William S. Prinz, who is Deputy Assistant Chief Geologist for Primary Minerals; Mr. Harold Kirkemo, Chief, Office of Minerals Exploration, and Mr. Reid Stone, who is our oil-shale coordinator within the Department of Interior.

With Dr. Osborn, Director of the Bureau of Mines, is Dr. John Morgan, who occupies the position of Assistant Director for Mineral Position Analysis, and Mr. Paul Zinner, the Assistant Director for Planning.

Representing the Office of Oil and Gas is Mr. John Ricca, its Acting Director.

And representing the Office of Minerals and Solid Fuels is Harry Moffett, Director of the Office, accompanied by John Shelton, one of his staff assistants.

With your permission, Mr. Chairman, I am only going to go through about half of my statement, with the suggestion that the full statement be inserted in the record.

Chairman PATMAN. It will be. And if you should discover after your testimony that you have overlooked something that you would like to supply for the record, it will be permissible for you to insert it in connection with your remarks.

Mr. DOLE. Thank you very much, Mr. Chairman.

In assessing our mineral position it is essential that we recognize that we cannot fulfill all of our mineral requirements from domestic sources. Mineral supply and demand are global in nature and thus preclude a policy of mineral self-sufficiency. It is obvious, therefore, that we must seek, on mutually favorable terms, access to supplies on the world market that are not available from domestic sources. At the same time, we must work to retain and expand world markets for U.S. mineral production in order to maintain favorable trade balances.

Chairman PATMAN. The object is to start and get up a program for the future and have additional hearings, we will say the last of August or the first part of September. It is very important that we get a good start and have the testimony printed. And we will have the benefit of this record for the other times that we have hearings. Don't you think that will be a good thing to do?

Mr. DOLE. I think that will be very fine, Mr. Chairman. And our testimony which will be developed by myself, the Director of the Bureau of Mines and others, will tend to form the basis by which you can expand and investigate in other areas.

Chairman PATMAN. In other words, suppose you do not deliver all of it, just the principal high points and put the prepared statement in the record. And then you call on the others you have named and indicated you would like to be heard, and have them take such time as is necessary and get their statements into the record. And then we will put other statements in the record too as a good start in this hearing.

Mr. DOLE. Fine, Mr. Chairman.

I hope that all of my statement and those of the others who are testifying here today will all be included in the record.

Chairman PATMAN. Fine, all of it will be included, including the tables. And these tables are very impressive.

Mr. DOLE. There is a proper balance between the basic national requirements of adequacy, security, and low cost of our mineral supplies. Congress last year enacted the Mining and Minerals Policy Act. This act imposes upon the Secretary of the Interior the tremendous responsibility of providing Congress annually with a report on the state of the mining industries together with recommendations on ways to encourage private enterprise to find and develop our mineral resources to the most efficient extent.

Congress has also enacted a measure establishing an independent seven-member Commission to review our overall materials requirements, except for food, and this will include our minerals situation. The Interior Department will play a leading role in this activity.

While we are concerned over our minerals capabilities and supply sources here at home, both developing and developed nations abroad are also mounting ever-increasing demands for mineral resources to improve their own standards of living. This situation in itself may eventually restrict the availability of foreign supplies to meet our needs.

Since 1940, an estimated $260 billion worth of minerals have been consumed in the United States. Prior to that date, total world consumption reached only an estimated $250 billion based on 1929 prices. Mineral consumption throughout the world is increasing more rapidly than in the United States and this trend, of course, brings about ever-increasing competition for raw materials and energy in world markets.

Our consumption of primary minerals including fuels in 1969 exceeded U.S. production by more than $8 billion. The demand for energy and minerals is expected to increase 3 to 5 times by the year 2000. Should the production trend of the past 20 years continue, the gap between demand and supply may be as high as $87 billion annually in constant 1969 dollars.

As pointed out above, foreign sources are likely to become less accessible to us because foreign consumption is increasing at a rate greater than our own. This situation, of course, makes it incumbent that we in the United States must step up the tempo of our exploration for new commercial mineral deposits both at home and abroad and increase our capability, through improved technology, to meet a larger part of our mineral supply needs through recycling and reclamation processes.

Costs of exploration and development are increasing rapidly. Some estimates place the total capital required to maintain existing operations and develop new ones during the next 5-year period at the staggering sum of $50 billion, including $3 billion in new capital to bring new mines to the production stage. Obtaining the necessary capital will be one of the major problems facing the mining industry in the future.

In the last 20 years we have seen strong shifts away from self-sufficiency for many mineral commodities such as bauxite, fluorspar, iron ore, rutile, and zinc, with no indication that future domestic resources will supply a significantly larger part of the national needs. Our self-sufficiency for such commodities as copper, lead, potash, and tungsten, does not show definite trends either way, but there is evidence that economic or technologic change could result in greater self-sufficiency. The United States is the major world source of magnesium, molybdenum, and sulfur and a net exporter.

The discovery and development of new reserves is difficult to assess. While the number of new discoveries has not been as great in recent years there have been significant discoveries such as Twin Buttes, Kalamazoo, and Lake Shore copper operations in Arizona, Carlin and Cortez gold operations in Nevada, zinc operations in central Tennessee, Spor Mountain beryllium operations in Utah, and extensions of the Idarado and Camp Bird base and precious metal deposits in Colorado. Production from overseas deposits has increased the total world supply of such materials as copper, lead, zinc, and petroleum. However, in recent years the nationalization of resources by some countries as well as increasing demand by developed as well as developing countries has threatened to decrease the availability of raw materials to the United States.

Changing economics and technology will have a significant impact on our ability to meet the expected expansions of our economy with the resultant increasing demands on raw materials and energy.

To be ready to solve today's problems and meet tomorrow's challenge we must reverse the trend toward fewer college and university students in mineral engineering and science. The number of mining departments at colleges and universities fell from 26 in 1962 to 15 in 1970. The number of mining, petroleum, metallurgical, and related engineering graduates fell from 1,480 in 1962 to 1,351 in 1966.

In examining the need for minerals engineers and scientists we must not forget the need for increasing numbers of skilled workers in the mines and in processing plants.

One of the problems to be dealt with in meeting future requirements will be the production of minerals and energy under conditions that meet the concerns at all levels of our Nation for environmental protection.

Cleaning up our environment and improving the utilization of our resources will be enhanced by successful efforts to recycle materials.

Many mineral substances can be replaced to some degree by substitution of alternate materials or development of new processes. Data are not available, however, to make quantitative conclusions concerning the extent and tendency of such substitutions.

It can be noted that in many cases the possible alternate materials are more costly or are in shorter supply than those they might supersede.

Data are not available on the costs to produce all the metal and mineral items. I wish to point out, however, that the rise in prices for minerals has been less than the overall inflationary increases of the economy in general. The growing emphasis on environmental protection is and will be a substantial factor in the upward pressure on costs.

Coal is expected to make a steady percentage contribution in filling U.S. energy needs. Coal supplied about one-fifth of the Nation's energy demand in 1970 and is expected to double in tonnage by the end of the century. This does not account for any additional demand that may prevail if economical processes for converting coal to gas or liquid fuels are developed.

The Department of the Interior through the Office of Coal Research is actively pursuing the development of processes for converting coal into synthetic pipeline gas and for producing low-sulfur liquid fuels from coal. The coal resources of the United States are sufficient to support a faster growth rate if coal should be called upon to furnish a greater share of U.S. energy demand for electric power generation, synthetic gas, and liquid fuels.

The attainment of the project goal for adequate coal inventories will require continued improvement in mining technology which will have to be accelerated to reduce mining costs and increase productivity. Also, a vigorous program of manpower recruitment and training will be necessary both in mining skills and in management (professionally trained personnel).

Since transportation is such an important part in the ultimate cost of coal to consumers, considerable investment will be required by railroads for new equipment to meet the needs of the coal industry.

Unless there is an improvement in the rate of discovery and development of oil and gas resources the expected increases in demand will bring about a greater reliance on imports.

Currently domestic oil production supplies about 77 percent of our petroleum products, but by 1985 U.S. production may supply only 55 percent of our needs for petroleum products.

In 1970 more than 75 percent of our energy requirements were met by oil and gas. The United States consumed almost 15 million barrels a day of petroleum and 22 trillion cubic feet per year of gas. In the 1980's the demand for petroleum is expected to be about 27 million barrels per day and the demand for gas, if available, will increase by 50 percent to 33 trillion cubic feet per year.

The Department is engaged in two programs to help meet our future growing energy needs—a proposed prototype program to recover oil from the vast oil shale province concentrated in Colorado, Utah, and Wyoming, and a program to utilize geothermal energy.

This concludes my brief summary of my fairly lengthy statement, Mr. Chairman.

Chairman PATMAN. We want all the information in the prepared statement in the record. And this will be a good start for us.

(The statement referred to follows:)

STATEMENT OF HON. HOLLIS M. DOLE, ASSISTANT SECRETARY OF INTERIOR—MINERAL RESOURCES

Mr. Chairman and members of the Committee, I appreciate the opportunity to appear before you today to discuss the production and demand for metals and minerals in the United States, the extent of our dependency upon foreign sources, and steps being taken to improve our supply situation through improved technology and reclamation and recycling of materials.

I am accompanied this morning by members of my staff and representatives from the U.S. Bureau of Mines, U.S. Geological Survey, and the Offices of Oil and Gas and Coal Research. Statements will be presented to you during the course of these hearings by Dr. Osborn, Director of the U.S. Bureau of Mines, Mr. Radlinski, Acting Director, U.S. Geological Survey, and John Ricca, Acting Director, Office of Oil and Gas.

In assessing our mineral position it is essential that we recognize that we cannot fulfill all of our mineral requirements from domestic sources. Mineral supply and demand are global in nature and thus preclude a policy of mineral self-sufficiency. Simply expressed we are not affluent in all mineral raw materials.

Our Nation is not now, nor will it likely ever be, self-sufficient in all the mineral raw materials that are essential to its needs. There are, in fact, certain mineral substances—tin for example—for which we are now, and to the best of our current knowledge, will continue to be almost wholly dependent upon foreign supply.

On the other hand, we produce surplus quantities of certain commodities and these compete successfully for overseas markets. It is obvious, therefore, that we must seek, on mutually favorable terms, access to supplies on the world market that are not available from domestic sources. At the same time, we must work to retain and expand world markets for U.S. mineral production in order to maintain favorable trade balances. And, all of this must be done while maintaining a substantial domestic mineral capability. There is a proper balance between the basic national requirements of adequacy, security, and low cost of our mineral supplies.

Recognizing the importance of developing overall mining and mineral policies to utilize domestic sources to the fullest and to foster our relations mineralwise with friendly and secure foreign sources, the Congress last year enacted the Mining and Minerals Policy Act. This Act imposes upon the Secretary of the Interior the tremendous responsibility of providing Congress annually a state of the mining industries report and formation of recommendations to encourage private enterprise to find and develop our mineral resources to the most efficient extent. We are currently in process of developing data for the first report due next January. It is our intent to study each of the mineral commodities needed to support our economy and security to determine production sources and rate of uses both at home and abroad and to delineate the problems facing our own mineral industries. This is an awesome task. It will not be accomplished in a short period of time. Development of mineral policies from among the many fragmented policies that are in effect today and administered by numerous agencies of Government cannot be welded together overnight. Congress has also enacted a measure establishing an independent 7-member Commission to review our overall materials requirements, except for food, and this will include our minerals situation. With respect to the latter it is expected that the Interior Department will play a leading role in this activity. This Commission does not have to report until June 30, 1973.

Both of these activities indicate the concern that exists in Congress, in the Executive Branch and across the Nation as to the future outlook for providing our Nation with the minerals necessary to meet ever-increasing demands for those products essential to the maintenance of our standard of living and security.

While we here at home are concerned over our minerals capabilities and supply sources, both developing and developed nations abroad are also mounting ever-increasing demands for mineral resources to improve their own standards of living. This situation in itself may eventually restrict the availability of foreign supplies to meet our needs.

Since 1940 an estimated 260 billion dollars worth of minerals have been consumed in the United States. Prior to that date, total world consumption reached only an estimated 250 billion dollars based on 1929 prices. Mineral consumption throughout the world is increasing more rapidly than in the United States and this trend, of course, brings about ever-increasing competition for raw materials and energy in world markets.

Our consumption of minerals including fuels in 1969 exceeded U.S. production by more than 8 billion dollars. This gap may widen in the years ahead. It is striking recognition of our increasing reliance on foreign supplies. Projections made by the Bureau of Mines for the year 2000 assume an annual increase in population at 1.6 percent, industrial production of 4.4 percent and real GNP of 4.4 percent. Based on these assumptions the demand for energy and minerals is expected to increase 3 to 5 times by the year 2000, an average annual rate of about 3.5 percent. Should the production trend of the past 20 years continue, the gap between demand and supply may be as high as 87 billion dollars in constant 1969 dollars. However, if the current level of self-sufficiency or ratio of domestic production to domestic consumption continues the gap will be about 40 billion dollars in constant 1969 dollars.

As pointed out above, foreign sources are likely to become less accessible to us because foreign consumption is increasing at a rate greater than our own. This situation, of course, makes it incumbent that we step up the tempo of our exploration for new mineral deposits both at home and abroad and increase our capability, through improved technology, to meet part of our mineral supply needs through recycling and reclamation processes.

Another complicating factor in our mineral supply situation is the fact that easily accessible high-grade ore deposits either have been or are being rapidly exhausted and their place must be taken by ore lying at greater depth or by ore of lower grade. Costs of exploration and development are increasing rapidly. Some estimates place the total capital required to maintain existing operations and develop new ones during the next 5-year period at the staggering sum of 50 thousand million dollars, including 3 thousand million dollars in new capital to bring new mines to the production stage. The tremendous financing requirements for mineral ventures make it virtually impossible for a single mining finance company to underwrite from its own resources all the funds needed for a major mining development. As a result, there has developed a strong trend towards joint ventures and the formation of consortiums on a multinational basis. Obtaining the necessary capital will be one of the major problems facing the mining industry in the future.

The degree of self-sufficiency of the United States in meeting its requirements for energy and minerals is of vital interest to the Department as it is to the Joint Committee on Defense Production.

In the last 20 years we have seen strong shifts away from self-sufficiency for many mineral commodities such as bauxite, fluorspar, iron ore, rutile and zinc, with no indication that future domestic resources will supply a significantly larger part of the national needs. Our self-sufficiency for such commodities as copper, lead, potash and tungsten, does not show definite trends either way, but there is evidence that economic or technologic change could result in greater self-sufficiency. The U.S. is the major world source of magnesium, molybdenum and sulfur and a net exporter.

The discovery and development of new reserves and resources is difficult to assess. In the early 1950's various incentives offered by the Government stimulated exploration and development for several metals. At that time the stockpile purchase program was in full operation as was the very successful Defense Minerals Exploration (DMEA) program. After completion of these programs and with declining prices activities virtually ceased at mica and tungsten operations while work continued on the better grade ores of other minerals. While the number of new discoveries has not been as great in succeeding years there have been significant discoveries such as Twin Buttes, Kalamazoo and Lake Shore copper operations in Arizona, Carlin and Cortez gold operations in Nevada, zinc operations in Central Tennessee, Spor Mountain beryllium operations in Utah and extensions of the Idarado and Camp Bird base and precious metal deposits in Colorado.

Other deposits are known or reserves at operating deposits have been expanded by the mining industry. Development of these reserves may be waiting in the wings for improved technologic or economic climate.

Recognizing the growing need for mineral and energy materials, the domestic mining industry has turned to exploration and development of mineral resources in foreign countries. Many of the deposits have been high grade and production costs have been lower than in the total United States. Production from overseas deposits has increased the total world supply of such materials as copper, lead, zinc and petroleum. However, in recent years the nationalization of resources by these countries as well as increasing demand by developed as well as developing countries has threatened to decrease the availability of raw materials for the United States.

Changing economics and technology will have a significant impact on our ability to meet the expected expansions of our economy with the resultant increasing demands on raw materials and energy. Advancing techniques for discovery and evaluations of mineral deposits have added to our known resources. Application of these techniques to broader areas such as examination of the earth's surface by orbiting satellites will discover new mineral and petroleum deposits. Many known deposits are complex or low grade and cannot be exploited under today's economics and technology. Another aspect of technology that affects our self-sufficiency is the development of alternate materials or new processes. The development of synthetic diamonds and quartz crystals has reduced our reliance on natural diamonds and quartz. Advances in electronics and the trend toward miniaturization have reduced our usage of strategic mica. We must continue to advance our state of the art and knowledge to effectively utilize marginal and unknown but to be discovered resources.

To be ready to solve today's problems and meet tomorrow's challenge we must reverse the trend toward fewer college and university students in mineral engineering and science. The challenges of the future will only be met by increasing academic interest in solving these problems and providing incentives that will attract more students. Improving our technology will fall to the mineral engineer and scientist. However, the number of mining departments at colleges and universities fell from 26 in 1962 to 15 in 1970. The number of mining, petroleum, metallurgical and related engineering graduates fell from 1,480 in 1962 to 1,351 in 1966, the last year data are available. The enrollment in these disciplines also dropped during these years indicating a continuing decline for the near future.

In examining the need for minerals engineers and scientists we must not forget the need for increasing numbers of skilled workers in the mines and in processing plants. The availability and time needed to train miners and other disciplines in the extractive industries have presented ever increasing problems.

One of the problems to be dealt with in meeting future requirements will be the production of minerals and energy under conditions that meet the concerns of all levels of our Nation for environmental protection. Environmental protection regulations have placed restrictions on amounts of materials that may be discharged into the waterways and the atmosphere and the disposition of waste materials from mining operations. Compliance with these regulations has restricted the use of plentiful high sulfur coal in many areas. The nonferrous smelting industry also is faced with the problem of developing methods or processes that meet State requirements for clean air. To date, the technology to reduce stack gas emissions is still in the research area. The Nation must support the efforts to provide a safer and more healthful environment by providing investments of money and trained people to develop and incorporate new technology and processes in our mining industry.

Cleaning up our environment and improving the utilization of our resources will be enhanced by successful efforts to recycle materials. The industry has long been recycling scrap material from their processing operations and returning secondary materials to the production stream but discarded or unusable waste is rapidly becoming a serious problem. Bureau of Mines programs promise to recover valuable products from such discarded or currently unusable waste materials as automobiles and trash and garbage incinerator residues.

Many mineral products can be replaced to some degree by alternate materials or processes such as those mentioned earlier as to diamonds, quartz and mica. Plastics and fiberglass products are intruding in the field once dominated by metals, one metal may replace another in some applications, combinations of metals or metals and nonmetals may enhance the properties of each and a different process may accomplish the same end. Data are not available, however, to make quantitative conclusions concerning the extent and tendency of such substitutions. The future trend may be the use of a material, combining the properties of several materials, designed to meet a specific requirement rather than designing the usage around the property of a metal or nonmetal.

It can be noted that in many cases the possible alternate materials are more costly or are in shorter supply than those they might supersede. Such substitutes usually entail some sacrifices of desirable properties or require alternate equipment or handling so that the alternate is resorted to only under pressure of very compelling economic considerations.

Data are not available on the costs to produce all the metal and mineral items. That the general inflationary rise of the economy is bringing about increases in present dollar production costs for almost all metals produced domestically is reflected in increased unit-value market price quotations. I wish to point out that the rise in prices for minerals has been less than the overall inflationary increases of the economy in general. This may be attributable in part to the mining industry's utilization of advanced methods for mining and treating mineral raw materials and in part to the lower unit costs at larger scale mining operations and the opportunities afforded by automation and mechanziation. The growing emphasis on environmental protection is and will be a substantial factor in the upward pressure on costs. Coal (bituminous, anthracite, lignite) is expected to make a steady percentage contribution in filling United States energy needs as they expand in the coming years through the end of the century. Coal which supplied about one-fifth of the Nation's energy demand in 1970 when nearly 527 million tons were consumed domestically (exclusive of 71.0 million tons exported) is expected to double in tonnage by the end of the century. This projection, which is based entirely upon the use of coal in its natural form, does not account for any additional demand that may prevail if economical processes for converting coal to gas or liquid fuels are developed. It may be expected that there will be some additional demand for coal in the latter years of the century because current research efforts indicate that gas and liquid fuels produced from coal will, eventually, be an addition to the energy markets with natural gas and petroleum. However, it does assume that evolving technology will enable coal to be utilized for power generation consistent with clear air requirements.

The Department of the Interior through the Office of Coal Research is actively pursuing the development of processes for converting coal into synthetic pipeline gas and for producing low-sulfur liquid fuels from coal.

There are three major projects for coal gasification. One large pilot plant has been completed and is in shakedown operation. A second is nearing completion and should be operable in 1972. A third is being designed and an expanded contract for its construction and operation is about to be executed. These programs will be accelerated in the coming years. Annual expenditure of $30 million (⅓ industry financing) a year for 4 or 5 years will establish the basis for the construction of a large demonstration plant in 1977 or 1978 and establishment of commercial coal gasification by 1980.

The Office of Coal Research also has three major projects for the development of processes for producing clean low-sulfur liquid fuels from coal designed to provide an alternate to dependence on foreign imports. One pilot plant is presently shut down pending decisions concerning its revamping to produce low-sulfur residual synthetic fuel oil. The other one is operating and it is expected that about two more years time will be needed to optimize the process. A third one, which produces a low-sulfur low-ash product, which can be burned in either liquid or solid form, is in the process development and pilot plant planning stage.

The coal resources of the United States are sufficient to support a faster growth rate if coal should be called upon to furnish a greater share of U.S. energy demand for electric power generation, synthetic gas, and liquid fuels. As shown in a statement presented by Secretary of the Interior Morton to the U.S. Senate Interior and Insular Affairs Committee on June 15, 1971, the known proved and measured reserves of coal are nearly 6 times larger than the combined oil, gas and uranium known reserves on a calorific basis and are sufficient to last centuries even with greatly expanded utilization.

The attainment of the project goal for coal inventories will require continued improvement in mining technology which will have to be accelerated to reduce mining costs and increase productivity. Also, a vigorous program of manpower recruitment and training will be necessary both in mining skills and in management (professionally trained personnel).

Since transportation is such an important part in the ultimate cost of coal to consumers, considerable investment will be required by railroads for new equipment to meet the needs of the coal industry. Water transport of coal will become increasingly important if coal is to supply its share of U.S. energy need. The low freight rate for barge movement (average 3 mills per ton mile) should enable coal to supply markets which otherwise remain beyond economic reach. The key factor regarding water transport is the construction and maintenance of locks on the river systems. Unless there is an improvement in the discovery and development of oil and gas resources the expected increases in demand will bring about a greater reliance on imports.

Currently domestic oil production supplies about 77 percent of our petroleum products, but by 1985 U.S. production may supply only 55 percent of our needs for petroleum products. By that time significant imports of gas may be required to meet expanding requirements.

Those familiar with petroleum and gas resources have estimated that we have found less than one-half of the discoverable oil and more than one thousand trillion cubic feet of gas remains in unknown deposits. The problem will be to find deposits that are large enough and recovery costs low enough to be economically attractive to private investors.

In 1970 more than 75 percent of our energy requirements were met by oil and gas. The United States consumed almost 15 million barrels a day of petroleum and 22 trillion cubic feet per year of gas. In the 1980's the demand for petroleum is expected to be about 27 million barrels per day and the demand for gas, if available, will increase by 50 percent to 33 trillion cubic feet per year.

The Department is engaged in two programs to help meet our future growing energy needs—a proposed prototype program to recover oil from the vast oil shale province concentrated in Colorado, Utah and Wyoming, and a program to utilize geothermal energy.

The oil shale province contains resources potentially valuable for development in excess of 80 billion barrels of shale oil. Major activity centers around the Department's prototype leasing program and the prototype operations which are underway by private industry.

Environmental reviews are currently being conducted by the Department in cooperation with other Federal and State agencies. Studies on land reclamation and control of air and water pollution will be conducted on a scale not previously attempted. Simultaneously, but independently, four private companies are expected to operate a prototype retort of nearly 1.000 barrels per day. We estimate that development of this resource can eventually add at least 3 million barrels per day of supplemental fuel to the Nation's supply.

Secretary Morton published proposed regulations for the development of geothermal steam resources on July 23, 1971. These resources offer a potential power production of an estimated 5,000 megawatts with a Federal royalty income estimated in the range of $5 million by 1985. Although this supplemental energy resource is not of the tremendous magnitude required to fully meet the Nation's growing energy needs, it can have a significant impact on local needs and thereby contribute by providing additional fuel for uses in other areas.

This concludes my statement. Dr. Elburt F. Osborn, Director of the Bureau of Mines, Mr. William A. Radlinski, Acting Director of the Geological Survey, and Mr. John Ricca, Acting Director of the Office of Oil and Gas, have prepared statements for presentation at this hearing. They, with members of their staff, and I along with my staff will be pleased to answer the questions of this Committee.

Chairman PATMAN. You may go ahead now and introduce the other witnesses and have them summarize their statements.

Mr. DOLE. I overlooked one of our important experts when I was introducing the people from the Department. I forgot to include Mr.

George Fumich, who is Director of our Office of Coal Research, upon which many of our new programs in coal depend.

Chairman PATMAN. You just handle it as you would like for it to be handled.

Mr. DOLE. All right, thank you, Mr. Chairman.

Following my presentation, Dr. Osborn, Director of the Bureau of Mines, will make the presentation. And he in turn will be followed by Mr. Radlinski, Acting Director of the Geological Survey, and then Mr. John Ricca of the Office of Oil and Gas.

Thank you, sir.

Chairman PATMAN. Thank you, sir.

And we will submit to you if you like a number of questions which we would like to have you answer when you look over your transcript to approve or disapprove it.

Mr. DOLE. We would be very pleased to have you do so. We would like to make this hearing as meaningful as we possibly can. Because our minerals and fuels policy is in my opinion one of the most important things we are facing today.

Chairman PATMAN. I know it is recognized that way, and it should be. It is very serious.

Mr. DOLE. Mr. Chairman, Dr. Osborn, Director of the Bureau of Mines.

Chairman PATMAN. Doctor, can you identify yourself and give your title and proceed in your own way.

Dr. OSBORN. My name is Elburt Osborn. I am Director of the Bureau of Mines.

Mr. Chairman, I have prepared here a written statement, a copy of which you have. And I hope that this may be included in the record.

Chairman PATMAN. As you have it, yes, sir, it will be included in the record. And that includes the valuable table on estimated supply and demand. I spent some time going over that table (page 25). I think it is very interesting. And you may proceed, sir, as you desire. And save a minute or 2 for each one of these tables, because I think the information is very valuable.

Dr. OSBORN. Mr. Chairman, I wonder, inasmuch as we have this written out, if it might be preferable if I were to make some extemporaneous remarks.

Chairman PATMAN. That will be satisfactory, and the entire statement will be put in the record.

Dr. OSBORN. I joined the Bureau of Mines just last fall. And so I am by now generally acquainted with the program of the Bureau of Mines which I think is one of the most important in the Federal Government with respect to the future of this country.

The Bureau is charged with the responsibility of assuring an adequate supply of mineral resources for this country. And in carrying out this mandate we work with industry, with labor, with the State governments, with the universities, and with other agencies within the Federal Government.

And one of the most interesting developments to me is the extent to which the Bureau of Mines program has moved into the social area, which is really what characterizes it, in the seventies. In other words, our program is moving along that very sensitive line between technology and people. The only significant increase in our budget this year is in this area, the particular aspects of it being the health and safety in the Nation's mines. And I would just like to dwell on this a little bit. We don't say much about it in the report.

There are three principal areas of what I am calling the social field. The first is health and safety in the extractive mineral industries. Certainly we have to improve this first because Congress is requiring it, and because it simply is essential from many other standpoints, as, for example, employment.

The second is the whole field of environment, where the mineral industry is more and more being called upon to do something about environmental problems with which it is involved in order to just continue to operate.

And the third field is that of education.

Now, briefly, on the first one, the matter of health and safety, we have three main thrusts in order to move as rapidly as we can on this. The Bureau of Mines was staggered by the job of enforcing the Coal Mine Health and Safety Act of 1969. It has been just a little over a year now that we have been involved in enforcing this law. We had to increase our inspection force from about 300 to over a thousand in order to do this job, which meant taking people from the mines, and incidentally from industry, and training these people to inspect properly.

I believe now we have our capabilities developed and that we are steadily moving ahead the way Congress wants us to and of course the way the President wants us to.

The three thrusts that I mentioned are just briefly this. The first is this one of enforcement. We can certainly make progress on cutting down the fatalities in the coal mines and reducing the general accident rate, and therefore also improving the rate of production, and so on, by regulation, by enforcement, by being a policeman. This is what we are to some extent. Also we have developed an assessment procedure which is fixing proposed fines on the coal companies for violations which our inspectors find. And these fines, up to about 2 months ago, amounted to over $5 million. These may be reduced after hearings, and so on. But unquestionably because of the regulations and our enforcement efforts, the coal mines are physically safer than they ever were before. The number of fatalities this year to date are the lowest they have ever been, which reflect to some extent, I think, the enforcement which we are carrying out.

The second program is one of research on coal mine safety. This country was behind other countries in coal safety. I think we were ahead in the technology of producing coal rapidly, but not in doing it safely. We are now trying to catch up, and Congress has provided the funds to do it. Traditionally the Bureau of Mines has done excellent work on making the coal mines safer—as, for example, work on explosives that are safer, permissible explosives, and work on roof bolting, and so on, which will make mines safer. We now have a program not only to catch up with what is the best mine safety technology in the world, but to get ahead of it, by such means as bleeding off the methane ahead of the mining, protecting the workers from roof falls by canopies because the largest single factor in fatalities is roof falls—and we are working on other means. Most of this research is being contracted out with industries and universities, but about a quarter of it is being done by our own laboratories.

So we are moving, and in another 2 or 3 years this research is going to be in the pay off.

And the third thrust on this is in the matter of education of the operators and the miners in safety, in other words, to develop a sense of safety.

We have right now approximately 60 full-time educators on our staff developing materials and giving courses to miners on safety, on first aid, and so on.

And so, just summarizing this tremendous program in health and safety, I would say that right now we are a policeman, and I think an effective one, in enforcing regulations, but as time goes on, more and more of our research and our education will begin to pay off. The mines will come into compliance with the law, and we hope there will be less and less fining and more and more safety.

The second of these areas which, as I say, is at this interface between humans and technology, is environment. Now, the Bureau of Mines is involved in doing something about the quality of the environment, not just talking about it.

Let me give you just two examples—there are many. One is the matter of sulfur dioxide emissions from smelters. The nonferrous metals, copper, lead, and zinc, are a big and basic industry in this country. I would be glad to introduce some figures on this into the record, because it is so important right now.

Chairman PATMAN. Please do. We would like to have them.

Dr. OSBORN. All right, sir. I would like to introduce two short reports that we have just written on this which call attention to this critical problem, and suggested solutions.

Even though it looks as if by expenditure of a few hundred million dollars the smelters may be able to meet the Federal standards, they are having serious trouble with local standards. I think the research work of the Bureau on methods of precipitating the sulfur dioxide and transforming it into elemental sulfur so that it can be stored is very important work, and we are working with industry on this problem.

The second area on environment that is notable because of the great work of the Bureau of Mines is on recycling of wastes. A good example of this work is that going on at College Park, Md., right nearby, on incinerator residues, where we are treating the residue from the Alexandria incinerator. We have developed a pilot plant there, and we have it operating and quite a few of our colleagues have been out to see it. It has received considerable attention in the newspapers. If this method is adopted by towns and by cities, it will mean the recycling of virtually all of the waste metals and nonmetals except the organic material, that is a problem we are working on separately, and putting them back into use. Wide adoption of this practice would help us with this problem of having to import materials such as copper, lead, zinc, aluminum, and so on, and at the same time substantially reduce the cost of disposing of the growing quantities of urban wastes. This is such an important aspect of our work on environmental problems that here again, with your permission, I would like to introduce several short reports on this subject.

Chairman PATMAN. Without objection it will be so ordered. We would be glad to have it, sir.

(For statement on the Control of Sulfur Oxide Emissions in Copper Smelting, see p. 99.)

(For statement on Sulfur Oxide Emission Standards and the Proposed Sulfur Emission Tax on the Domestic Nonferrous Smelting Industry in Copper Smelting, see p. 143.)

(For statement on Bureau of Mines Accomplishments in Recycling Solid Wastes, see p. 157.)

Chairman PATMAN. Before you came in we had an understanding, Mr. Brown, that we would get all these statements in today, and then we will prepare questions, you can and I will too, and other members, and submit them, and the witnesses will answer those questions when they look over their transcripts.

And I think that you would be willing to have Mr. Brown help me on the preparation of questions that we have in mind. I hope that is satisfactory.

Dr. OSBORN. We would be very glad to do that.

Chairman PATMAN. Mr. Dole.

Mr. DOLE. Mr. Chairman, we would like to refer to these materials that Dr. Osborn was just mentioning as "urban ore." And we consider that to be the only mineral deposit that is increasing in size and quantity in the United States.

Furthermore, I would like to extend to you and your committee an invitation to visit our plant at College Park.

Chairman PATMAN. We have that in mind. It has already been discussed.

Mr. DOLE. I hope that you can make it. We can do it within one morning's time.

Chairman PATMAN. Fine. Thank you.

Go ahead, Dr. Osborn.

Dr. OSBORN. I have emphasized these social problems, the health and safety of the mines, and the environment, because this is so important to the life of the mineral industries, and also therefore the security of this country.

The third area is the education one. Here we have the problems that Secretary Dole referred to starting with the problem of education of the workers, especially miners, and particularly training men to go into the mines. There is a tremendous shortage of miners right now, especially in the coal mining industry, which is greatly handicapping the industry. Just in the central and western Pennsylvania area over a thousand new miners are needed which are not available. We are working with the Labor Department and HEW—the Labor Department putting up the money, because this is in their bailiwick—but we are administering the program of training miners. And just last week I was in Leadville, Colo., to see the program there, where there are 18 trainees. These are unemployed people who are being paid to take this course and to go into the mining industry. They will go into the general western Colorado plateau area. We also have schools in Virginia, in Montana, and in central Pennsylvania, and we have a new experimental one in Pennsylvania. So on that level we are beginning to work, but not fast enough to provide the manpower that industry needs.

Secondly, we have the education program on the health and safety of the miners who are already employed. And I have already referred to that.

And thirdly, the matter that Secretary Dole mentioned that concerns us very greatly is the one of the lowly state of the mining schools or mining engineering programs in the universities. Although I do not think it needs to be introduced into the record, I would like to refer to the report of the National Academy of Sciences Committee on Mineral Science and Technology issued in 1969, which discusses this very serious problem for the mineral industries.

And the problem, Mr. Chairman, is this, a Government program in research and development to be highly successful, must have a base in the universities. For example, the space program is supported by great physics departments and electrical engineering departments, in the Nation's universities and so on.

The U.S. Geological Survey draws upon the great geology departments. They are strong professionally because they have very large numbers of students in the universities taking geology. Therefore you have the student credit hours and therefore a continuing support of a large staff of geology. So we have real strong geology departments and the Geological Survey is fortunate in that they have a good base in universities, not only to provide people for the staff of the Geological Survey, but to do much of the real good geological science research in the country. But in the case of minerals engineering, mining engineering, petroleum mining, extractive metallurgy, ceramics materials, and mineral economics, the little we once had is gone. We can't hire people, even if we had money—and we did have a little—for research in universities, there isn't the necessary competence there.

And so we in the Bureau of Mines, and in Secretary Dole's office, are doing everything we can to encourage through contracts and through visiting and working with them, the development of better programs in the universities.

Lastly, Mr. Chairman, I would like to mention that traditionally an exceedingly important part of the Bureau of Mines work has been that of providing the basic data and developing these charts that you were just referring to.

We are continuing, and we think improving, this whole factfinding program of the Bureau. But in addition, as you can see from the organization chart, we are improving our analytical capabilities.

Chairman PATMAN. That is very interesting. We are very anxious to have these in the record. (See p. 24.)

Dr. OSBORN. If you will turn to this you will notice over on the right side is an office called Assistant Director of Mineral Position Analysis. This is a new organization which we have just created. Dr. Morgan, who is here, is head of this. This group is charged with the responsibility of using the great volume of mineral statistics and information that we have developed, and interpreting the findings, in other words, analyzing these statistics, and trends.

Chairman PATMAN. I notice you are projecting all your estimates here to the year 2000.

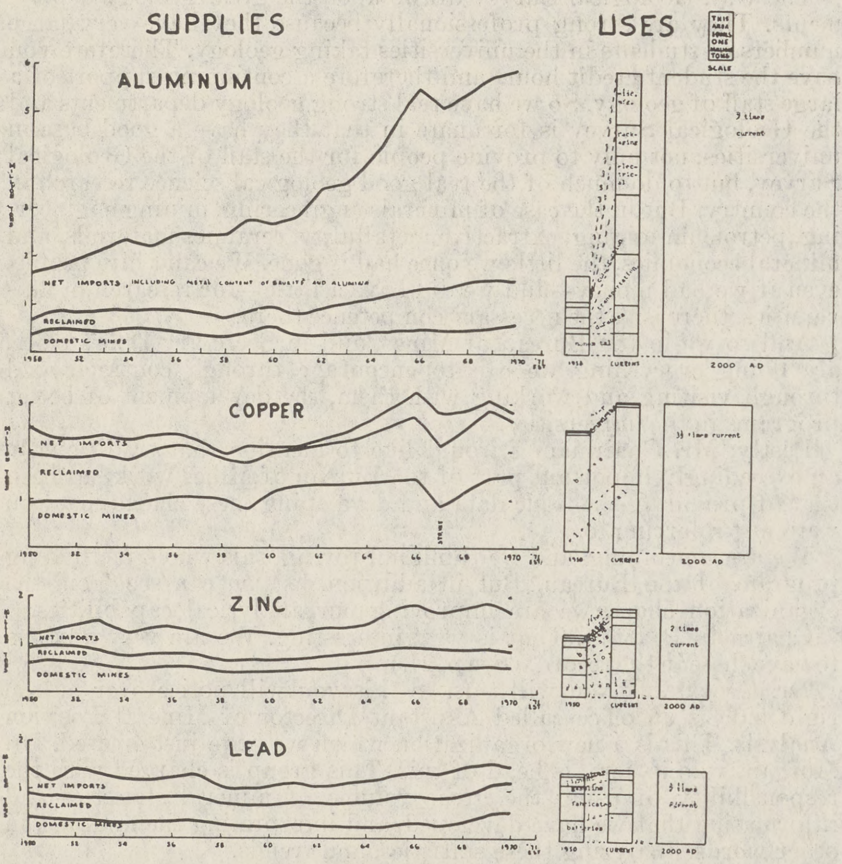
Dr. OSBORN. Yes, sir.

Chairman PATMAN. I wonder if you could go beyond that safely.

Dr. OSBORN. How far would you like?

Chairman PATMAN. Well, whatever your studies indicate that we should be considering.

Dr. Osborn. Well, we have been thinking in terms of 30 years. But we could go, say, to 50, and make some guesses on that. I would like to call your attention to the type of new chart that we are developing. That is the small one right on your right hand. For purposes of illustration we show just four commodities, aluminum, copper, zinc, and lead. Take aluminum, for example. The curve shows the net imports, the material that we are reclaiming, and the material we are getting from domestic mines. On the right it gives a breakdown of the uses. I think this type of illustration might be useful to you people. We can provide this type of presentation for any of a hundred or so commodities, which at a glance give us the picture.



Chairman Patman. How many commodities have you listed on these charts?

Dr. Osborn. I think there are 91 on the charts.

Chairman Patman. You give all the information that is material for our consideration about the U.S. production and demand and the projected U.S. demand.

Dr. OSBORN. And it gives two different ways of showing the sad situation the United States is likely to be in in the year 2000, two different means of showing it there.

Chairman PATMAN. You mean shortages of vital materials?

Dr. OSBORN. Yes, sir.

Chairman PATMAN. Of course we know a lot of them. But which materials would you consider the most important in our considerations?

Dr. OSBORN. Well, to start at the top of the list, aluminum is a very serious problem right now.

Chairman PATMAN. You mean as to a possible shortage?

Dr. OSBORN. With respect to the fact that the raw materials are almost all from outside. The very large domestic manufacturing extraction and manufacturing facilities rely upon foreign raw material sources. It is certainly one of the emerging problems.

Chairman PATMAN. It certainly could be a real serious one.

All right, sir, you may go ahead, sir.

Dr. OSBORN. I believe, Mr. Chairman, that I would like to close. You have the full written statement.

(The statement referred to follows:)

STATEMENT OF DR. ELBURT F. OSBORN, DIRECTOR, BUREAU OF MINES

Mr. Chairman and members of the Committee, it is both a real pleasure and a great opportunity for me to appear before this Committee to describe the work of the Bureau of Mines in furthering the policies and programs described in the previous testimony. While this is my first appearance before the Joint Committee on Defense Production, I have long been conscious of the impact of the Defense Production Act in strenghtening the materials position of the United States.

In the World War II period, I was engaged in research work on materials for the Office of Scientific Research and Development, and then from 1946 until joining the Bureau of Mines in October 1970, I served successively as Professor of Geochemistry, Dean of the College of Mineral Industries, and Vice President for Research at the Pennsylvania State University. In these connections, I had continuing contact with problems of mineral supply and usage and I followed with interest the many programs in these fields that were initiated under the Defense Production Act of 1950 as amended. The current "20th Annual Report of the Activities of the Joint Committee on Defense Production" reflects clearly the basic broad concern with national materials problems that have involved many of us in the last twenty years.

Starting in 1966 and continuing through 1969, I had an additional major opportunity to survey the United States mineral position as a consequence of my having been asked to chair the Committee on Mineral Science and Technology that had been established by the National Academy of Sciences to determine the state of mineral science and technology in the United States and to provide information and recommendations regarding its health and effectiveness. The report of our committee entitled "Mineral Science and Technology—Needs, Challenges and Opportunities," together with five supporting panel reports were issued by the National Academy of Sciences in 1969. These reports documented the decline in fundamental research and education in the mineral field in the United States and made a number of recommendations intended to reverse what we viewed as a profoundly disturbing long-term trend.

In the years immediately following the issuance of our 1969 report, I and the other members of our committee have received constant confirmation that the downward trends regretfully were continuing. Consequently, when I was asked to head the Bureau of Mines in October of 1970, I viewed this assignment as both a real challenge and a real opportunity to carry out many of our recommendations, particularly those dealing directly with the Bureau of Mines. One of my first steps was to establish a new Office of University Relations to help me try to reverse the unfortunate trend in domestic mineral education and research.

The Bureau of Mines was established in 1910, over 60 years ago. The original Act of May 16, 1910, as amended by the Act of February 25, 1913, reflected the genuine concern of the Government for materials problems at that early time. Indeed, the duties of the Bureau as stated then were remarkably well conceived so as to reflect broadly much of what must be done at the present time. The original Act set forth the duties of the Bureau of Mines as follows:

"It shall be the province and duty of the Bureau of Mines, subject to the approval of the Secretary of the Interior, to conduct inquiries and scientific and technologic investigations concerning mining, and the preparation, treatment, and utilization of mineral substances with a view to improving health conditions, and increasing safety, efficiency, economic development, and conserving resources through the prevention of waste in the mining, quarrying, metallurgical, and other mineral industries; to inquire into the economic conditions affecting these industries; to investigate explosives and peat; and on behalf of the Government to investigate the mineral fuels and unfinished mineral products belonging to, or for the use of, the United States, with a view to their most efficient mining, preparation, treatment, and use; and to disseminate information concerning these subjects."

There have been additions to this basic charter over the years, and the Bureau of Mines has also received additional authority through delegations and assignments pursuant to other legislation, including the Defense Production Act of 1950 as amended. In recent years, the Bureau has received increasing responsibilities for mine safety, culminating in the Federal Coal Mine Health and Safety Act of 1969, and the Metal and Nonmetallic Mine Health and Safety Act of 1966.

The importance of mineral materials to the national economy has been recognized in many other pieces of legislation. Indeed within the last year, the Mining and Minerals Policy Act of 1970 (PL 91–631) and the National Materials Policy Act of 1970 (PL 91–512) both gave added recognition to the important role of minerals and materials in the national economy. We estimate that the value of domestic mineral raw materials in 1971 will reach $31 billion. Added to this will be imports of mineral raw materials valued at about $3 billion. These mineral raw materials, when processed by the United States mineral processing industries, including energy generation and transmission, will result in mineral based products: fuels, electricity, brick, tile, glass, metals, concrete, chemicals, plastics, fertilizers, and so forth, valued at over $150 billion. These mineral products, together with imports of mineral based products valued at about $8 billion, directly support the United States economy in which total GNP is valued at over $1,050 billion. Thus, it can be seen that minerals support directly at least 15 percent of our GNP. However, without this 15 percent, there would be no GNP except for life at a primitive level; for the minerals provide the bulk of most of our energy, which is equivalent to 300 working individuals for each one of the over 205 million people in the United States today, as well as over 10 tons of mineral solid materials per citizen per year.

Over the years, through my many contacts with the United States Bureau of Mines and the Geological Survey I developed a high regard for the professional competence of these organizations. However, it is always possible to improve existing organizations, and at times redirection of efforts must be initiated to reflect changing circumstances and changing priorities. Indeed the rate of change in the world today in many fields is accelerating. Consequently, when I became the Director of the Bureau of Mines, one of my first major tasks was to assure that the organization and the personnel were fully geared not only to the tasks of today but also to the years ahead. I know that highly qualified professional men often can perform very ably even though organizational lines may not be precisely defined or appropriate. Likewise, I know that careful organization, supplemented by modern data processing facilities, can greatly assist professional people in improving analyses, conclusions, and recommendations. Accordingly, in the past nine months I have visited many of the major field operations of the Bureau to see their work first-hand. I believe that the molding of a proper organization should be an evolutionary rather than revolutionary process and that human and humane considerations are perhaps equally, if not more, important than cold analytical considerations. Thus, I have been gradually engaged in shaping the Bureau's structure toward what I believe to be a more functional and responsive organization.

The present organization chart of the Bureau of Mines (attached) reflects our current views as to what is needed at this time to properly discharge both our current operational responsibilities and our long-term planning and analytical responsibilities. The Bureau is divided into two major areas, each under the operational direction of a Deputy Director.

One major area is Health and Safety, and the other is Mineral Resources and Environmental Development. We have recently enlarged the number of coal mine safety field installations from 5 district offices to 9 district offices to better accomodate the increasing activity in the field of coal mine safety. Several of these 9 districts also have subdistrict offices in major centers of coal mine activity. We also have 6 district offices supervising metal and nonmetal safety, and in education and training largely directed toward safety, we have 9 field installations. Through enforcement of the health and safety laws, we are contributing what we can toward making mining of all types a stable industry that will stand a better chance of attracting and holding the skilled personnel that are so necessary in these days of declining grades of ores and more stringent product specification requirements.

In the Mineral Resources and Environmental Development Area, we have five major subdivisions: Energy (with 9 field research centers), Metallurgy (with 8 field research centers), Mining (with 4 field research centers), Mineral Supply (with 4 field centers), and Mineral Position Analysis. It is in these many research centers and laboratories that the ongoing forward-looking scientific research and development of the Bureau is carried on. Here our many skilled scientists, supported by appropriate technologists, are probing the earth and its undeveloped resources for processes and products that at some future time will result in either new materials, improved materials, or better ways of recovering materials from low-grade deposits or from presently considered wastes. I am sure that you would find a visit to any of our research centers a most interesting experience and I wish to extend to you a sincere invitation to visit any of them at any time. Perhaps the closest to Washington, D.C. is the one at College Park, Maryland, where our mineral recycling research, including recovery from trash, has received widespread publicity.

Do our research efforts bear fruit? Perhaps one example closest to the province of the Joint Committee on Defense Production is provided by research of the Bureau of Mines during and shortly after World War II in perfecting on a laboratory scale the Kroll Process for the production of titanium metal through reduction of titanium tetrachloride in an inert atmosphere using magnesium metal. When there arose a great demand for titanium metal in military and aerospace applications after the start of the Korean War, the titanium metal expansion program was undertaken under authority of the Defense Production Act of 1950 as amended. Today there are 3 titanium metal producers in the United States, jointly owned by large chemical companies and steel companies, and titanium is contributing its high strength-weight and corrosion-resistant properties to defense and defense related production.

In the field of mining research, the Bureau of Mines developed techniques for supporting loose overhead rock strata through the technique of roof bolting. This technique is now common in coal mines of the United States and has facilitated increased usage of mechanized equipment by providing larger open spaces than would have been possible if timbering or other closely-spaced supports were still needed.

In its health and safety research, the Bureau of Mines has led the way in establishing standards limiting quantities of respirable dust in all forms of mining. At the same time, the Bureau has developed and tested various filtering devices to reduce the incidence of silicosis and pneumoconiosis. The Bureau several years ago developed a small portable methane detector which is easier to read and lighter to carry than the flame safety lamp detector which had been in use virtually unchanged for over 100 years. This small detector is now being manufactured commercially.

The Bureau of Mines at its Rifle, Colorado, station did pioneer work in the underground mining of oil shale and in the technology for retorting such oil shale to recover the oil contained therein. This work has led private industry to continue work at their own expense and has greatly encouraged further interest in leasing for ultimate development of the oil shale resources of the Western lands.

At Bartlesville, Oklahoma, and at other research stations, the Bureau of Mines did extensive work in secondary recovery of oil that heretofore had been left in oil sands. The water-flooding techniques have served to extend United States reserves of petroleum. To improve extractive ratios the Bureau has made many detailed studies and carried on extensive research in reservoir engineering.

Several Bureau research projects have accomplished dual policy objectives. For example, the development of a smokeless incinerator for burning old cars has eliminated air pollution that previously resulted from open-air burning, while also improving the quality of scrap metal recovered from the furnace. The development of light-weight construction materials from coal fly-ash lends added incentive to removal of fly-ash from power plant stack gases, while also providing a new source of construction materials.

The development of processes to convert garbage to liquid fuels and waste glass in trash to road aggregates not only will conserve materials and recycle them but also will help to reduce the need for garbage disposal methods inimical to the environment.

We could list many more examples where Bureau research has paid off in later commercial processes but I know that the time of this Committee is limited and I wish, therefore, to turn to our mineral position research which I know is of direct interest to the members of this committee at this time.

The Bureau of Mines is the focal point in the United States Government for the collection and analysis of data dealing with the mineral industry. Our commodity divisions—Ferrous Metals, Non-Metallic Minerals, Non-Ferrous Metals, and Fossil Fuels—under our Assistant Director for Mineral Supply are engaged in worldwide collection of essential information dealing with mineral deposits, mineral production, and mineral usage. We collect information on up to 100 distinct mineral commodities coming from more than 150 countries of the world. And, of course, particularly detailed information is sought on the mineral industries of each of our 50 United States. The collection and analysis of this information is essential to the operation of scores of other Government Agencies, to United States industry, and to the worldwide operations of the mineral industry.

We annually publish statistics in the "Minerals Yearbook" series which is the standard reference volume not only for the United States but for the world.

The Bureau of Mines issues statistical information in preliminary form in some cases on a weekly basis and in others on monthly or quarterly bases. This fundamental information is drawn upon by such agencies as the Tariff Commission, Federal Trade Commission, Federal Power Commission, Interstate Commerce Commission, and many other Federal Agencies as they discharge their responsibilities. While there are always some dangers in attempts to issue statistics promptly, it is our philosophy that we should put out information as quickly as possible, using partial estimation techniques where necessary. Perhaps one of the best examples of our operations in issuing summary statistics promptly in convenient form is the annual publication, "Commodity Data Summaries," copies of which were sent to the members of the Committee, and of which I have here some extras. This publication contains in capsule form materials of direct interest to this Committee. For those wishing more in-depth analysis, the Bureau recently issued a revised edition of its major study, "Mineral Facts and Problems," which is a detailed commodity-by-commodity analysis, including forward projections, that runs over 1200 pages in length.

The Bureau issues scientific and technological information as rapidly as the facts that it develops can be ascertained. To put such information in the hands of interested Federal, State, and local Government Agencies and industry, the Bureau issues a wide variety of information circulars and bulletins. These publications are promptly indexed in national professional publications and hence rapidly come to the attention of interested parties.

To assist us in discharging the increased responsibility devolving upon the Bureau as a consequence of the National Mining and Minerals Policy Act and the National Materials Policy Act, the Bureau is intensifying its analytical activities through a new Assistant Director for Mineral Position Analysis. Drawing upon information already available in the Bureau, this new function is pointing out additional areas where further information is needed. It is coordinating with other Bureaus within the Department of the Interior and with Agencies outside the Department in developing analyses of the mineral position of the United States in the light of the rapidly changing technological and international scenes.

Assessing the role of the domestic mining and minerals industry of the United States is becoming increasingly complex in recent years as a consequence of acceleration of horizontal and vertical integrations of corporations, formation of unrelated conglomerate amalgamations, joint ventures, and consortiums. Operations tend increasingly to cross national boundaries. Foreign nations are pressing for more of the income resulting from the "value added" in processing mineral raw materials. In some ways these developments may tend to promote cross-fertilization of new technologies and the rapid introduction of more efficient methods, but at the same time traditional long-standing commercial arrangements are being sundered. Likewise, the tendency in many parts of the world toward nationalization of resources and government control of mineral sales makes the United States position more tenuous. Recent expropriation of copper mines in Chile is only the latest example of many such happenings. Moreover, the United States no longer enjoys the unique, commanding position that it held in world mineral markets some years ago. The growth of the Common Market and Japan to the point that each produces an annual tonnage of steel approximating our own is introducing new competitive factors into world mineral markets. Japan is aggressively making worldwide long-term contracts to assure itself of mineral supplies. Perhaps the Japanese have learned from the USA just how effective long-term contracts are in developing assured mineral supplies, as was so ably demonstrated in the case of the domestic mineral expansion programs carried out in the USA under the aegis of the Defense Production Act! And, while not yet a major factor in world markets, the USSR has already surpassed the USA in coal production, and perhaps this year it will equal the USA in steel production.

While the Bureau publications that I referred to earlier in my testimony contain much basic information, one of the major problems confronting all of us involves the distilling of such information down to its essentials so that those charged with policy determinations can more readily be apprised of changing trends. Toward this end I should like to give this Committee some current examples of analytical work in progress. The two large tables attached compare the United States primary mineral supply demand relationships that existed in 1969 with those that are anticipated for the year 2000 A.D. The constant ratio column (A/B) shows at a glance for each commodity our degree of self-sufficiency (number of 1.00 = self-sufficient, while 0.00 = completely dependent upon imports).

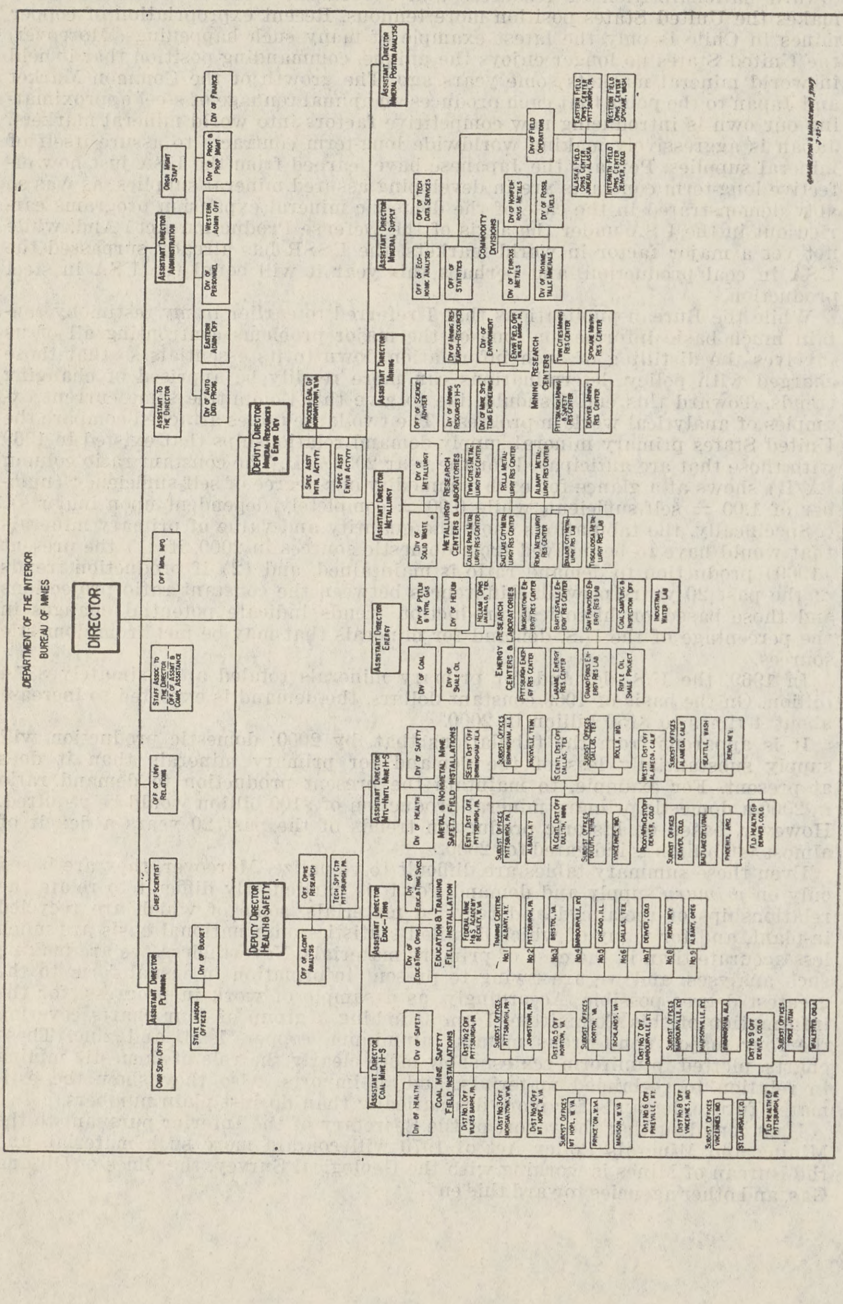
Specifically, the tabulations show the quantity and value of primary minerals that would have to be derived from domestic sources in 2000, if (1) the present (1969) production to demand ratio is maintained, and (2) if production trends of the past 20 years prevail. Differences between the constant ratio projections and those based on historical production trends indicate potential changes in the percentage of the U.S. demand for minerals that may be met from domestic sources.

In 1969, the U.S. demand for primary minerals totaled approximately $37.4 billion. On the basis of 1969 constant dollars, the demand is expected to increase about 4 times to $150 billion in 2000.

It is apparent from the tabulations that, by 2000, domestic production will supply substantially less of the demand for primary minerals than it does at present. For example, to maintain the present production to demand ratio in 2000 a domestic primary mineral production of $109 billion would be required. However, based on historic production trends of the past 20 years a deficit of almost $46 billion is indicated for 2000.

Even these summary tables are difficult to visualize. Moreover, they are based only on *primary* supply and demand, for it is particularly difficult to relate the relationships of reclaimed and recycled materials, some of which are recycled in-plant, and for many of which detailed statistics on a national basis are much less accurate than in the case of primary materials. Nevertheless, we are making such analyses, and we are trying to present information in visual form to the greatest degree possible. Accordingly, as a sample of work in progress, for the information of this Committee, I am attaching a group of four charts covering the four major non-ferrous metals: aluminum, copper, lead, and zinc. These charts, plotted to uniform scales, show more clearly the role of domestic mining in relation to reclaimed materials, and to imports. Also they show the estimated future demands far more dramatically than do just plain numbers.

I am confident that the report of the Secretary of the Interior pursuant to the Mining and Minerals Policy Act of 1970 will contain more such material, and the Bureau of Mines is working with the Geological Survey, the Office of Oil and Gas, and other agencies toward this end.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2-25-71

COMPARISON OF PREVAILING U.S. PRIMARY MINERAL SUPPLY-DEMAND RATIOS WITH PROJECTED HISTORICAL TRENDS IN DOMESTIC MINERAL PRODUCTION

Commodity	Units	1969			2000			
		A U.S. primary production	B U.S. primary demand	A/B Constant ratio	C Projected U.S. primary demand	D U.S. primary production if 1969 constant ratio prevails	E U.S. primary production if past 20-year trends prevail	F Departure from constant ratio (difference between D and E)
Aluminum	Thousand short tons	500	5,100	0.098	35,000	3,430	400	−3,030
Antimony	Short tons	2,218	20,689	.107	48,000	5,136	0	−5,136
Arsenic	do	(1)	(1)	.325	38,000	12,350	6,500	−5,850
Barium	Thousand short tons	603	899	.671	1,300	872	510	−362
Beryllium	Short tons	(1)	(1)	.858	1,300	1,115	146	−969
Bismuth	Thousand pounds	(1)	2,539	.388	4,000	1,552	323	−1,229
Boron	Thouand short tons	171	86	1.988	303	602	331	−271
Bromine	Million pounds	335	327	1.024	500	512	586	74
Cadmium	Thousand pounds	4,650	14,324	.325	30,000	9,750	4,700	−5,050
Calcium	Thousand short tons	89,190	89,190	1.000	283,000	293,000	125,000	−168,000
Cesium	Pound	0	(1)	0	20,000	0	0	0
Chlorine	Thouand short tons	9,422	9,419	1.000	42,050	42,250	18,800	−23,450
Chromium	do	0	475	0	1,120	0	0	0
Cobalt	Thousand pounds	1,000	18,900	.053	24,700	1,309	0	−1,309
Columbium	do	0	4,660	0	19,150	0	0	0
Copper	Thousand short tons	1,545	1,696	.911	6,100	5,557	2,132	−3,425
Fluorine	do	82	603	.136	2,400	326	27	−299
Gallium	Kilogram	(1)	(1)	1.764	820	1,446	687	−759
Germanium	Thousand pounds-troy	30	17	1.765	30	53	0	−53
Gold	Thousand troy ounces	1,733	6,567	.264	14,300	3,775	1,140	−2,635
Hafnium	Short ton	0	(1)	0	50	0	0	0
Indium	Thousand troy ounces	(1)	(1)	.380	800	304	415	111
Iodine	Thousand pounds	(1)	4,902	.151	15,500	2,341	409	−1,932
Iron	Million short tons	59	90	.656	150	98	44	−54
Lead	Thousand short tons	509	873	.583	1,429	833	257	−576
Lithium	Short tons	(1)	(1)	1.043	10,855	11,322	5,415	−5,907
Magnesium, metal	Thousand short tons	100	102	.980	495	485	156	−329
Magnesium, nonmetal	do	1,110	1,140	.974	2,160	2,104	1,800	−304
Manganese	do	93	1,317	.071	2,357	167	0	−167
Mercury	Thousand fluid liters	29	69	.420	90	38	52	14
Molybdenum	Thousand pounds	99,807	57,287	1.742	187,600	326,799	177,000	−149,799
Nickel	do	31,200	299,200	.104	770,000	80,080	85,000	4,920
Nitrogen, compounds	Thousand short tons	10,611	9,940	1.068	39,700	42,400	19,832	−22,568
Nitrogen, gas and liquid	do	4,879	4,879	1.000	22,500	22,500	11,903	−10,597

See footnote at end of table.

COMPARISON OF PREVAILING U.S. PRIMARY MINERAL SUPPLY-DEMAND RATIOS WITH PROJECTED HISTORICAL TRENDS IN DOMESTIC MINERAL PRODUCTION—Continued

Commodity	Units	1969			2000			
		A U.S. primary production	B U.S. primary demand	A/B Constant ratio	C Projected U.S. primary demand	D U.S. primary production if 1969 constant ratio prevails	E U.S. primary production if past 20-year trends prevail	F Departure from constant ratio (difference between D and E)
Palladium	Thousand troy ounces	10	531	.019	1,060	20	23	3
Phosphorus	Thousand short tons	5,099	3,400	1.500	12,000	18,000	11,339	−6,661
Platinum	Thousand troy ounces	11	389	.028	1,000	28	3	−25
Potassium	Thousand short tons	2,327	3,901	.597	12,000	7,164	3,559	−3,605
Rare earths	Short ton	(1)	11,000	1.331	22,000	29,282	29,000	−282
Rhenium	Pound	2,500	1,250	2.000	12,700	25,400	7,000	−18,400
Rhodium	Thousand troy ounces	0	38	0	85	0	3	3
Rubidium	Pound	0	(1)	0	2,200	0	0	0
Scandium	Kilogram	(1)	5	3.200	17	54	37	−17
Selenium	Thousand pounds	1,199	1,426	.841	1,620	1,362	1,100	−262
Silicon	Thousand short tons	471	477	.987	1,003	990	818	−172
Silver	Thousand troy ounces	41,900	98,500	.425	210,000	89,000	31,800	−57,200
Sodium	Thousand short tons	18,994	19,919	.954	67,230	64,137	33,384	−30,753
Strontium	Short ton	0	(1)	0	19,080	0	0	0
Sulfur	Thousand long tons	9,540	9,175	1.040	30,000	31,200	14,600	−16,600
Tantalum	Thousand pounds	0	1,287	0	4,010	0	0	0
Tellurium	do	234	312	.750	366	275	230	−45
Thallium	Pound	(1)	(1)	.949	9,000	8,541	4,600	−3,941
Thorium	Short ton	(1)	(1)	.775	1,500	1,163	36	−1,127
Tin	Long ton	(1)	58,015	.001	90,000	90	0	−90
Titanium, metal	Thousand short tons	0	27	0	168	0	0	0
Titanium, nonmetal	do	302	508	.594	1,810	1,075	610	−465
Tungsten	Thousand pounds	7,439	15,556	.478	74,000	35,372	6,300	−29,072
Vanadium	Short ton	5,900	8,000	.738	31,000	22,900	13,800	−9,100

Yttrium	do	(1)	(1)	.353	420	148	32	−116
Zinc	Thousand short tons	553	1,504	.368	3,000	1,104	388	−716
Zirconium, metal	Short ton	0	(1)	0	20,000	0	0	0
Zirconium, nonmetal	Thousand short tons	(1)	(1)	.526	167	88	104	16
Asbestos	do	126	784	.161	1,574	253	260	7
Clays	Million short tons	59	57	1.035	170	176	90	−86
Corundum	Short ton	0	2,000	0	1,100	0	0	0
Diatomite	Thousand short tons	667	491	1.358	2,000	2,716	1,300	−1,416
Feldspar	Thousand long tons	674	708	.952	2,500	2,380	1,012	−1,368
Garnet	Thousand short tons	20	17	1.176	53	62	38	−24
Graphite	do	(1)	(1)	.049	90	4	0	−4
Gypsum	do	9,881	15,818	.625	35,000	21,875	10,000	−11,875
Kyanite	do	(1)	(1)	1.157	630	729	280	−449
Mica, scrap and flake	do	133	134	.993	448	445	230	−215
Mica, sheet	Thousand pounds	(1)	6,584	.001	600	(600)	0	−(600)
Perlite	Thousand short tons	471	455	1.035	1,320	1,366	936	−430
Pumice	do	3,609	3,992	.904	12,000	10,848	8,553	−2,295
Sand and gravel	Million short tons	937	936	1.001	3,200	3,203	1,956	−1,247
Stone, crushed	do	646	646	1.000	2,517	2,517	1,638	−879
Stone, dimension	Thousand short tons	1,873	1,873	1.000	3,820	3,820	2,595	−1,225
Talc	do	1,029	941	1.094	2,920	3,194	1,525	−1,669
Vermiculite	do	309	250	1.236	725	896	515	−381
Anthracite	do	10,473	8,809	1.189	2,300	2,735	0	−2,735
Bituminous coal and lignite	Million short tons	561	507	1.107	1,200	1,328	600	−728
Natural gas	Billion cubic feet	20,700	20,400	1.015	49,000	50,000	40,100	−9,900
Peat	Thousand short tons	572	872	.656	2,200	1,443	1,590	147
Petroleum	Million barrels	3,952	5,160	.766	12,000	9,200	6,200	−3,000
Shale oil	do	0	0	0	1,500	0	0	0
Uranium	Short ton	10,069	4,070	2.474	61,000	150,914	30,500	−120,414
Argon	Thousand short tons	148	148	1.000	560	560	301	−259
Helium	Million cubic feet	760	759	1.001	2,500	2,503	2,500	−3
Hydrogen	Billion cubic feet	2,163	2,163	1.000	10,500	10,500	4,642	−5,858
Oxygen	Thousand short tons	12,840	12,840	1.000	65,000	65,000	32,500	−32,500

[1] Certain data are withheld because the manner in which the information became available to the Bureau of Mines does not permit general disclosure.

COMPARISON OF VALUE OF U.S. PRIMARY MINERAL PRODUCTION AND DEMAND IN 1969 WITH PROJECTED VALUE IN 2000

Commodity	Price units	Average unit price—1969 dollars: 1969	Average unit price—1969 dollars: 2000	Value—Million 1969 dollars: Primary demand: 1969	Primary demand: 2000	Primary production: 1969	Primary production: 2000: A If 1969 constant ratio prevails	Primary production: 2000: B If past 20-year trends prevail	Departure from 1969 constant ratio difference A and B
Aluminum	Pound	0.272	0.37	2,774.4	25,900.0	272.0	2,538.2	296.0	−2,242.2
Antimony	do	.5757	.70	23.8	67.2	2.5	7.2	0	−7.2
Arsenic	Short ton	168.00	180.00	[1]	6.8	[1]	2.2	1.2	−1.0
Barium	do	24.12	27.00	21.7	35.1	14.5	23.5	13.8	−9.7
Beryllium	Pound	60.00	60.00	[1]	156.0	[1]	133.8	17.5	−116.3
Bismuth	do	4.63	5.00	11.8	20.0	[1]	7.8	1.6	−6.2
Boron	Short ton	469.77	500.00	40.4	151.5	80.3	301.0	165.5	−135.5
Bromine	Pound	.26	.26	85.0	130.0	87.1	133.1	152.4	19.3
Cadmium	do	3.27	3.50	46.8	105.0	15.2	34.1	16.5	−17.6
Calcium	Short ton	4.07	4.00	363.0	1,172.0	363.0	1,172.0	500.0	−672.0
Cesium	Pound	.60	.60	[1]	.01	0	0	0	0
Chlorine	Short ton	74.00	74.00	697.0	3,126.5	697.2	3,126.5	1,391.2	−1,735.3
Chromium	do	145.00	175.00	68.9	196.0	0	0	0	0
Cobalt	Pound	2.20	2.20	41.6	54.3	2.2	2.9	0	−2.9
Columbium	do	1.70	1.50	7.9	28.7	0	0	0	0
Copper	do	.479	.75	1,624.8	9,150.0	1,480.1	8,335.5	3,198.0	−5,137.5
Fluorine	Short ton	102.95	135.00	62.1	324.0	8.4	44.0	3.6	−40.4
Gallium	Gram	.70	.70	[1]	.6	[1]	1.0	.5	−.5
Germanium	Pound	84.00	120.00	1.4	3.6	2.5	6.4	0	−6.4
Gold	Troy ounce	41.51	80.00	272.6	1,144.0	71.9	302.0	91.2	−210.8
Hafnium	Pound	85.00	85.00	[1]	8.5	0	0	0	0
Indium	Troy ounce	2.50	3.00	[1]	2.4	[1]	.9	1.2	.3
Iodine	Pound	1.24	2.00	6.1	31.0	[1]	4.7	.8	−3.9
Iron	Short ton	15.65	18.65	1,408.5	2,797.5	923.4	1,827.7	820.6	−1,007.1
Lead	Pound	.1493	.16	260.7	457.3	152.0	266.6	82.2	−184.4
Lithium	do	.91	.90	[1]	19.5	[1]	20.4	9.7	−10.7
Magnesium—Metal	do	.3525	.30	71.9	297.0	70.5	291.0	93.6	−197.4
Magnesium—Nonmetal	Short ton	79.88	80.00	91.1	172.8	88.7	168.3	144.0	−24.3
Manganese	do	44.60	44.60	58.7	105.1	4.1	7.4	0	−7.4
Mercury	Flask	505.00	700.00	34.8	63.0	14.6	26.6	36.4	9.8
Molybdenum	Pound	1.72	1.82	98.5	341.4	171.7	594.8	322.1	−272.7

Nickel	do	1.28	1.45	383.0	1,116.5	39.9	116.1	123.3	7.2
Nitrogen—Compounds	Short ton	60.00	52.50	596.4	2,084.3	636.7	2,226.0	1,041.2	−1,184.8
Nitrogen—Gas and liquid	do	20.05	14.20	97.8	319.5	97.8	319.5	169.0	−150.5
Palladium	Troy ounce	42.00	75.00	22.3	79.5	.4	1.7	1.7	0
Phosphorus	Short ton	38.24	50.00	130.0	600.0	195.0	900.0	567.0	−333.0
Platinum	Troy ounce	125.00	165.00	48.6	165.0	1.4	4.6	.5	−4.1
Potassium	Short ton	31.62	40.00	123.3	480.0	73.6	286.6	142.4	−144.2
Rare earths	Pound	.35	.35	7.7	15.4	(1)	20.5	20.3	−.2
Rhenium	do	665.00	800.00	.8	10.2	1.7	20.3	4.6	−14.7
Rhodium	Troy ounce	235.00	300.00	8.9	25.5	0	0	.9	.9
Rubidium	Pound	.37	.60	0	----------	0	0	0	0
Scandium	Grain	4.08	4.08	.02	.07	(1)	.2	.1	−.1
Selenium	Pound	7.00	6.00	10.0	9.7	8.4	8.2	6.6	−1.6
Silicon	Short ton	272.00	300.00	129.7	300.9	128.1	297.0	245.4	−51.6
Silver	Troy ounce	1.79	2.70	176.3	567.0	75.0	240.3	85.9	−154.4
Sodium	Short ton	18.48	18.50	368.1	1,243.8	351.0	1,186.5	617.6	−568.9
Strontium	do	47.25	55.00	(1)	1.0	0	0	0	0
Sulfur	Long ton	25.00	25.00	229.4	750.0	238.5	780.0	365.0	−415.0
Tantalum	Pound	9.15	15.00	11.8	60.2	0	0	0	0
Tellurium	do	6.00	6.00	1.9	2.2	1.4	1.7	1.4	−.3
Thallium	do	7.50	7.50	(1)	.07	(1)	.06	.03	−.03
Thorium	do	7.97	8.00	(1)	24.0	(1)	186	.6	−18.0
Tin	do	1.64	3.00	213.1	364.9	(1)	.5	0	−.5
Titanium—Metal	do	1.32	1.20	71.3	403.2	0	0	0	0
Titanium—Nonmetal	Short ton	960.00	1,160.00	487.7	2,099.6	289.9	1,247.0	707.6	−539.4
Tungsten	Pound	2.62	4.00	40.8	296.0	19.5	141.5	25.2	−116.3
Vanadium	do	3.15	3.00	50.4	186.0	37.2	137.4	82.8	−54.6
Yttrium	do	9.00	13.50	(1)	11.3	(1)	4.0	.9	−3.1
Zinc	do	.1465	.20	440.7	1,200.0	162.0	441.6	155.2	−286.4
Zirconium—Metal	do	6.00	6.00	(1)	240.0	0	0	0	0
Zirconium—Nonmetal	Short ton	116.00	116.00	(1)	19.4	(1)	10.2	12.1	1.9
Total				11,939.5	58,741.9	6,943.7	27,789.6	11,737.9	−16,051.7
Asbestos	Short ton	105.00	130.00	82.3	204.6	13.2	32.9	33.8	.9
Clays	do	4.50	6.50	256.5	1,105.0	265.5	1,144.0	585.0	−559.0
Corundum	do	21.23	25.00	.04	.03	0	0	0	0
Diatomite	do	60.96	61.50	29.9	123.0	40.7	167.0	80.0	−87.0
Feldspar	Long ton	13.16	13.50	9.3	33.8	8.9	32.1	13.7	−18.4
Garnet	Short ton	91.60	90.00	1.6	4.8	1.8	5.6	3.4	−2.2
Graphite	do	41.00	50.00	(1)	4.5	(1)	.2	0	−.2
Gypsum	do	3.88	3.90	61.4	136.5	38.3	85.3	39.0	−46.3
Kyanite	do	91.00	98.00	(1)	61.7	(1)	71.4	27.4	−44.0
Mica—Scrap and flake	do	24.05	25.00	3.2	11.2	3.2	11.1	5.8	−5.3
Mica—Sheet	Pound	.70	.70	4.6	.4	----------	----------	0	----------
Perlite	Short ton	10.82	11.00	4.9	14.5	5.1	15.0	10.3	−4.7
Pumice	do	1.11	1.20	4.4	14.4	4.0	13.0	10.3	−2.7
Sand and gravel	do	1.14	1.30	1,067.0	4,160.0	1,063.2	4,163.9	2,542.8	−1,621.1
Stone—Crushed	do	1.54	1.60	994.8	4,027.2	994.8	4,027.2	2,620.8	−1,406.4

BUREAU OF MINES—Continued

COMPARISON OF VALUE OF U.S. PRIMARY MINERAL PRODUCTION AND DEMAND IN 1969 WITH PROJECTED VALUE IN 2000—Continued

Commodity	Price units	Average unit price—1969 dollars		Value—Million 1969 dollars					
				Primary demand		Primary production			Departure from 1969 constant ratio difference A and B
							2000		
		1969	2000	1969	2000	1969	A If 1969 constant ratio prevails	B If past 20-year trends prevail	
Stone—Dimension	Short ton	52.67	44.20	98.7	168.8	98.7	168.8	114.7	−54.1
Talc	do	7.30	8.00	6.9	23.4	7.5	25.6	12.2	−13.4
Vermiculite	do	21.95	28.00	5.5	20.3	6.8	25.1	14.4	−10.7
Total				2,644.0	10,114.1	2,568.9	9,988.2	6,113.6	−3,874.6
Anthracite	Short ton	9.62	12.40	84.7	28.5	100.8	33.9	0	−33.9
Bituminous coal and lignite	do	4.99	6.00	2,529.9	7,200.0	2,799.4	7,968.0	3,600.0	−4,368.0
Natural gas	Thousand cubic feet	.167	.42	3,406.8	20,580.0	3,456.9	21,000.0	16,842.0	−4,158.0
Peat	Short ton	12.47	12.50	10.9	27.5	7.1	18.0	19.9	1.9
Petroleum	Barrel	3.09	3.40	15,944.4	40,800.0	12,211.7	31,280.0	21,080.0	−10,200.0
Shale oil	do	3.09	3.40	0	5,100.0	0	0	0	0
Uranium	Pound	6.90	20.00	56.2	2,440.0	138.8	6,036.4	1,220.0	−4,816.4
Total				22,032.9	76,176.0	18,714.7	66,336.3	42,761.9	−23,574.4
Argon	Short ton	285.00	200.00	42.2	112.0	42.2	112.0	60.2	−51.8
Helium	Thousand cubic feet	30.00	60.00	22.8	150.0	22.8	150.2	150.0	−.2
Hydrogen	do	.245	.35	529.9	3,675.0	529.9	3,675.0	1,624.7	−2,050.3
Oxygen	Short ton	11.75	10.50	150.9	682.5	150.9	682.5	341.3	−341.2
Total				745.8	4,619.5	745.8	4,619.7	2,176.2	−2,443.5
Grand total				37,362.2	149,651.5	28,973.1	108,733.8	62,789.6	−45,944.2

[1] Certain data are withheld because the manner in which the information became available to the Bureau of Mines does not permit general disclosure.

Dr. OSBORN. I will answer any questions you have.

Chairman PATMAN. That is all right, we will submit the questions in writing, we want a good record made of this hearing. And if you see, Mr. Dole, that we are lacking in some areas, if you will call it to our attention and help us supplement it, it will be appreciated very much. This is very important right now.

Mr. DOLE. Mr. Chairman, I certainly appreciate your interest in this. And I guarantee that we will do something.

Chairman PATMAN. Thank you, sir.

Mr. DOLE. And now, Mr. Chairman, I would like to present to you Mr. William Radlinski, who is the Acting Director of the Geological Survey. You will recall that Doctor William Pecora, who was the Director of our Geological Survey, has recently been elevated to the position of Under Secretary of Interior. Mr. Radlinski has with him three people today. He will present his statement, and I am sure he also will respond to you in the best way possible.

Chairman PATMAN. Thank you, sir.

We are delighted to have you. You may proceed as you desire.

Mr. RADLINSKI. Thank you, Mr. Chairman.

At your suggestion I will also brief my statement here. And I would like to briefly review two activities of the Geological Survey that are pertinent to the work of this committee.

The first is our on-going research program in the field of mineral and fuel resources. And the second is the Office of Minerals Exploration program successor to the Defense Minerals Exploration Administration established under the Defense Production Act.

The resource programs of the Geological Survey are broad ranging, from gathering basic geological data covering the Nation, to the identification of potential ore bearing regions, to the development of geochemical and geophysical techniques for mineral and fuel exploration, and to the appraisal of the resources of the Nation. Basic geologic studies and particularly geologic mapping, are fundamental to these resource activities. A geologic map comprises the basic information used to identify our areas with resource potential and to narrow down the area in which to search for new ore deposits. Geologic knowledge forms the essential foundation for a meaningful resource appraisal, and the more complete our knowledge of the geologic framework of an area, the more precise our appraisal of the resource in that area will be.

Coupled with this program of basic geological research and related geochemical and geophysical studies, the Geological Survey prepares resource appraisals for particular regions or commodities. On a regional basis we have over the past years compiled resource summaries for 13 States, mainly in the West, and for the Appalachian region here in the East, and in response to the Wilderness Act of 1964, we are appraising the resource potential for Forest Service lands being considered for inclusion in the Wilderness System.

On a commodity basis the Geological Survey resource specialists are conducting a limited program of national and worldwide resource appraisal for particular mineral or energy commodities and are investigating means for improving the precision of resource appraisals.

Domestic resources of many commodities are very small or are so low grade that the outlook for their being economically exploitable in the near future is poor. These commodities include bauxite, chromite, columbium, diamond, manganese, sheet mica, nickel, tantalum and tin. Improvements in technology or the identification of new resources could change the long range outlook for some of these commodities, but for a few, particularly chromite and manganese, considerable effort has been expended in the past and the outlook for increased domestic production is expected to remain dim.

On the brighter side, we feel that the long range domestic resource situation for several commodities, particularly the base metals—appears good. In the years ahead we can anticipate increasing the domestic resource base for these commodities and the development of new recoverable reserves through the discovery of new deposits and through improvements in technology.

In addition to our resource appraisal function, the Survey is responsible for administering the Office of Minerals Exploration (OME) loan program established under Public Law 85–701, which was enacted on August 21, 1958. OME was set up within the Department of Interior, and then eventually in the Geological Survey. This particular program has limitations. For example, under the OME, no funds can be made available to applicants if financing is available from commercial sources on reasonable terms. In other words, an applicant has to take a pauper's oath, so to speak. Government participation in a single contract is limited to $250,000. Because of these limitations the OME program has failed to encourage the private sector to participate as expected, and the level of activity and the results achieved have been disappointing. A comparison of the OME program with the previous program, the DMEA program, is given in the table in my statement here.

Thank you.

(The statement referred to follows:)

STATEMENT OF W. A. RADLINSKI, ACTING DIRECTOR, GEOLOGICAL SURVEY

Mr. Chairman, members of the Committee: Today, I would like to briefly review two activities of the Geological Survey that are pertinent to the work of the Committee. The first is our ongoing research program in the field of mineral and fuel resources, and the second is the Defense Mineral Exploration Administration program established under the Defense Production Act and its successor program—the Office of Minerals Exploration.

The Geological Survey is responsible for appraising the mineral and fuel resources of the United States, for increasing the domestic resource base from which recoverable reserves can be developed as the need arises, and for developing the exploration concepts and techniques necessary to convert undiscovered resources into discovered useable reserves.

The importance of resources cannot be overemphasized in the long-term mineral and energy supply picture. For example—the recent discovery of recoverable reserves of copper from previously undiscovered resources in the Southwestern United States is enabling us to better meet the demands of domestic copper consumers from domestic sources. Likewise, the vast but previously uneconomic known resources of iron in the taconites of the Lake Superior region were converted into economically recoverable reserves in the 1950's through the development and application of new technologies, and we have thus been able to maintain a viable domestic iron mining industry. In the long-range copper supply picture, we anticipate that low-grade copper deposits of the type that we are now studying in some of the ancient rocks of northwestern Montana and adjacent Idaho will be as important to copper supply as taconite has been to iron industry.

The resource programs of the Geological Survey are broad ranging—from gathering basic geologic data covering the Nation, to the identification of potential ore-bearing regions, to the development of geochemical and geophysical techniques for mineral and fuel exploration, and to the appraisal of the resources of the Nation. Basic geologic studies, and particularly geologic mapping, are fundamental to all resource activities. A geologic map comprises the basic information used to identify areas with resource potential and to narrow down the area in which to search for new ore deposits. Geologic knowledge forms the essential foundation for a meaningful resource appraisal, and the more complete our knowledge of the geologic framework of an area, the more precise our appraisal of the resources of that area will be. Unfortunately, however, at the present time only about one-third of the country is mapped geologically in detail adequate for really good resource appraisal purposes and for this reason, we place a high priority on our basic geologic mapping program.

Coupled with this program of basic geological research and related geochemical and geophysical studies, the Geological Survey prepares resource appraisals for particular regions or commodities. These appraisals are prepared as part of our ongoing resource program or in response to external requests, and they are generally synthesized from currently available geological, geophysical, and geochemical data with the addition of new data as funding and time constraints permit. Because new information that may affect resources estimates is continually being generated, the resource appraisal process is not static and no appraisal can be considered final. All are subject to reevaluation and revision in the light of newly generated information.

On a regional basis, we have, over the past several years, compiled resource summaries for 13 States—mainly in the West—and for the Appalachian region here in the East, and in response to the Wilderness Act of 1964, we are appraising the resource potential of Forest Service lands being considered for inclusion in the Wilderness System. In anticipation of an increasing need for more detailed resource information on specific tracts of land—particularly as related to public land use planning—we have started this year pilot studies in several selected areas to compile and synthesize all pertinent resource data on a scale of one inch equals four miles. As part of these pilot studies, we are also experimenting with computer storage and handling of basic resource data.

On a commodity basis, Geological Survey resource specialists are conducting a limited program of national and worldwide resource appraisal for particular mineral or energy commodities and are investigating means for improving the precision of resource appraisals. Over the past several years, comprehensive resource appraisals have been prepared for several commodities—including bauxite (aluminum), tin, iron, and coal—and a summary compilation covering all important commodities was published in our 1968 annual review. Data for selected commodities from this compilation are in a table attached to this statement. This resource compilation is now undergoing review in preparation for incorporation in the Secretary of the Interior's first annual report on the status of the domestic minerals industry as required under P.L. 91–631, the Mining and Minerals Policy Act of 1970.

Domestic resources of many commodities on this table are very small or are so low grade that the outlook for their being economically exploitable in the near future is poor. These commodities include bauxite, chromite, columbium, diamond, manganese, sheet mica, nickel, tantalum, and tin. Improvements in technology or the identification of new resources could change the long-range outlook for some of these commodities, but for a few—particularly chromite and manganese—considerable effort has been expended in the past and the outlook for increased domestic production is expected to remain dim.

On the brighter side, we feel that the long-range domestic resource situation for several commodities on the table—particularly the base metals—appears good. In the years ahead, we can anticipate increasing the domestic resource base of these commodities and the development of new recoverable reserves through the discovery of new deposits and through improvements in technology.

In addition to our resource appraisal function, the Geological Survey is responsible for administering the Office of Minerals Exploration loan program and the residual obligations from its predecessor—the Defense Minerals Exploration Administration program. The DMEA program under the Defense Production Act provided financial assistance to private industry in order to stimulate exploration for new sources of critical and strategic minerals and metals in the United States, its Territories, and possessions. The program was established to assure sufficient ore supplies to meet shortages of mineral and metal for defense and essential civilian industry during the Korean emergency, and to provide a broader mobilization base to meet future emergencies.

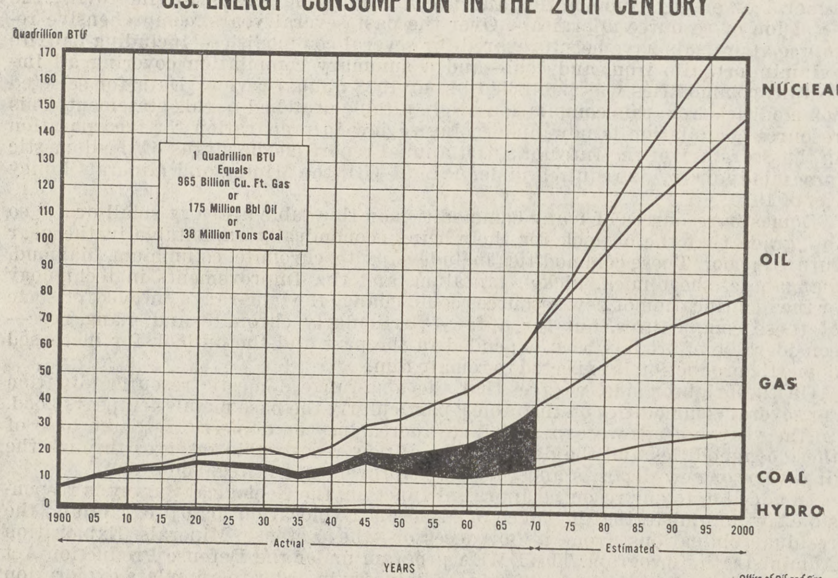
Exploration conducted under the DMEA program is credited with the discovery of mineral reserves valued at about $1 billion. The Government's financial contribution to the exploration totalled about $23.3 million of which nearly one-third had been repaid through royalties on production through June 30, 1971. As royalty obligations will continue on some contracts until 1989, repayment will be even greater. In addition to royalties, taxes paid by producers on production must be considered a benefit to the Government.

By mid-1958, stockpile objectives of most mineral commodities had either been filled or future deliveries were assured, so the borrowing authority which had supported the DMEA program was terminated on June 30, 1958. No new contracts were executed thereafter though contracts then in effect continued in accordance with their provisions until completed. Work on the last contract was finished in 1962.

On August 28, 1958, the Congress enacted Public Law 85–701 which authorized another program to stimulate minerals exploration. Accordingly, the Office of Minerals Exploration (OME) was established in the Department of the Interior and has been in continuous operation since—first as an independent office and, since July 1, 1965, under the Geological Survey. Though the goals of the OME program are generally similar to the DMEA, there are certain important differences. Under OME, no funds can be made available to applicants if financing is available from commercial sources on reasonable terms; DMEA contained no such provision. Government participation in a single contract is limited to $250,000—there was no ceiling under DMEA. Because of these limitations, the OME program has failed to encourage the private sector to participate as expected and the level of activity and the results achieved have been disappointing as the statistics in the attached table show. Ways of correcting the deficiencies in the OME program are currently under review.

We thank you for affording us the opportunity to appear here today and look forward to continuing working with you in the future.

U.S. ENERGY CONSUMPTION IN THE 20th CENTURY



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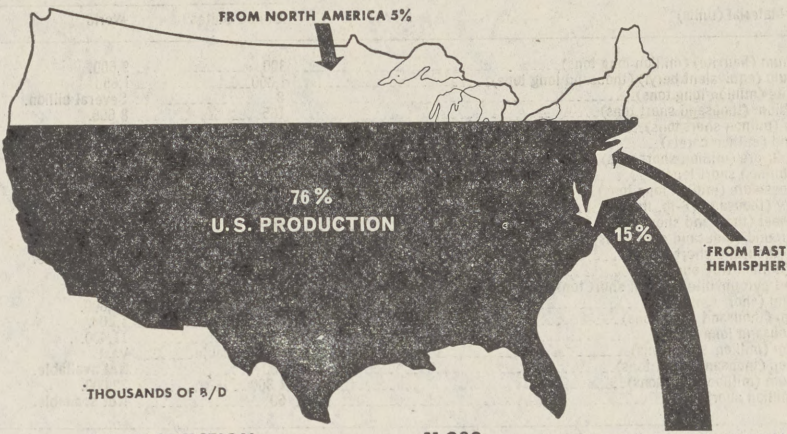
March 1972

1970 U.S. DEPENDENCY ON OIL IMPORTS



THOUSANDS OF B/D

U.S. PRODUCTION	11,280
NORTH AMERICAN IMPORTS	700
SOUTH AMERICAN IMPORTS	2,200
EASTERN HEMISPHERE IMPORTS	530
TOTAL SUPPLY	14,710

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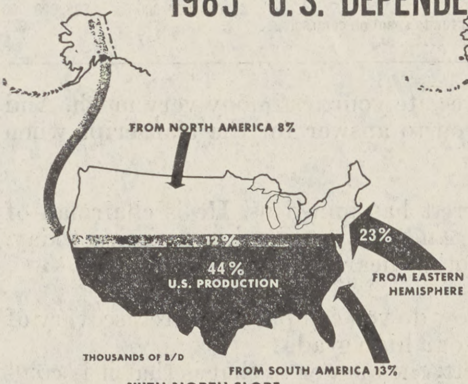
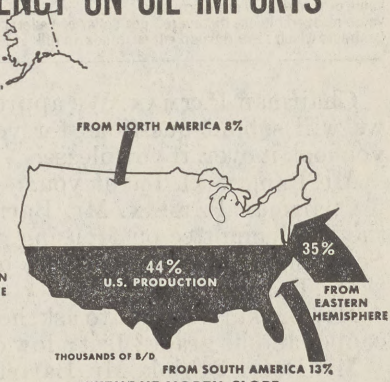
1985 U.S. DEPENDENCY ON OIL IMPORTS



THOUSANDS OF B/D

WITH NORTH SLOPE

U.S. PRODUCTION	11,600
ALASKA NORTH SLOPE	3,000
NORTH AMERICAN IMPORTS	2,200
SOUTH AMERICAN IMPORTS	3,500
EASTERN HEMISPHERE IMPORTS	6,150
TOTAL SUPPLY	26,450



THOUSANDS OF B/D

WITHOUT NORTH SLOPE

U.S. PRODUCTION	11,600
ALASKA NORTH SLOPE	--
NORTH AMERICAN IMPORTS	2,200
SOUTH AMERICAN IMPORTS	3,500
EASTERN HEMISPHERE IMPORTS	9,150
TOTAL SUPPLY	26,450

Office of Oil and Gas
Department of the Interior
March 1971

RESOURCES OF SELECTED MINERALS THAT RELATE TO THE NATIONAL STOCKPILE

[Compiled from U.S. Geological Survey Professional Paper 600–A, p. A13–A14, 1968]

Material (units)	Resources	
	United States	World
Aluminum (bauxite) (million long tons)	300	9,600.
Beryllium (equivalent beryl) (thousand long tons)	1,000	1,650
Chromite (million long tons)	8	Several billion.
Columbium (thousand short tons)	165	8,600.
Copper (million short tons)	65	Not available.
Diamond (million carats)	0	Do.
Fluorspar ore (million short tons)	22	170.
Lead (million short tons)	15	Not available.
Manganese ore (million long tons)	1,000	15,000.
Mercury (thousand 76-lb. flasks)	750	15,000.
Mica-sheet (thousand short tons)	Small	Large.
Mica-ground (thousand short tons)	Large	Very large.
Nickel (thousand short tons)	1,400	Not available.
Silver (million troy ounces)	500	Do.
Talc and pyrophyllite (million short tons)	Large	Do.
Tantalum (short tons)	Not available	95,000.
Thorium (thousand short tons)	215	1,200.
Tin (thousand long tons)	43	11,400.
Titanium (million short tons)	Not available	Vast
Tungsten (thousand short tons)	200	Not available.
Vanadium (million short tons)	1,300	20,000.
Zinc (million short tons)	60	Not available.

Note: World totals include United States. U.S.S.R. excluded for columbium and tantalum.

SALIENT STATISTICS COMPARING THE D.M.E.A. AND O.M.E. PROGRAMS

	D.M.E.A.	O.M.E
Applications received, annual average	555	69
Contracts executed, annual average	165	15
Jobs created by new contracts annually, average 8 per contract	1,320	120
Value of recoverable ore discovered	$1,000,000,000	$95,000,000
Value recoverable ore discovered per dollar of Federal funds spent on contracts	$48	$23
Contracts which have repaid Federal funds in full	97	5

Chairman PATMAN. We appreciate your testimony very much. And we will submit questions for you to answer for the transcript when you look it over, if you please.

Mr. RADLINSKI. Thank you.

Chairman PATMAN. Mr. Barrett has joined us. He is chairman of the Subcommittee on Housing. And they are having a session today. So we have some conflict with other hearings in our committee.

Mr. Barrett.

Mr. BARRETT. I want to ask, how do you compare your rediscovery of copper and its grade? Is it a low or a high grade?

Mr. DOLE. I think, Mr. Barrett, the answer to that is that it is commercial. As you know, the grade of copper has gone down in the past 20 years from about 2 percent to an average grade of around 0.6 percent. So we are looking at these copper deposits within the 0.6 range. However, it is not only the ability, the improved technology to refine this ore that has allowed us to develop these lower grade sources, but also the development of new earth moving methods or mining methods, and materials handling methods. So that it is anticipated that we can go down below 0.5 percent, in other words, 10 pounds per ton in the very near future. The grade of these ores is similar to the grade of other porphyry copper deposits of the Far West.

Mr. BARRETT. Thank you.

Chairman Patman. Go ahead, Mr. Dole.

Mr. Dole. Mr. Chairman, I would like to call now Mr. John Ricca, Acting Director of the Office of Oil and Gas.

Chairman Patman. Mr. Ricca, we are delighted to have you, sir, and you may proceed as you desire.

Mr. Ricca. Thank you, Mr. Chairman. And as you have suggested, I will only highlight my statement, and then you can incorporate the full statement in the record.

Chairman Patman. Certainly. It will be incorporated in the record as you have presented it.

Mr. Ricca. I will only take a few minutes to highlight the statement.

Oil and gas now, Mr. Chairman, supply about three-quarters of our energy requirements in the United States. Our problem for the future is how to meet the growing energy requirements without dangerous dependence on overseas imports.

In 1970 the United States consumed nearly 15 million barrels a day of petroleum products, and about 23 percent of this was imported.

Now, by 1985 we are going to consume some 12 million barrels a day above this, or close to 27 million barrels a day. And if we don't keep up with our production requirements domestically, by 1985 we will reach as much as 45 percent that will have to be imported.

For the past several years the levels of drilling and exploration in the United States have not been able to prevent declines in both proved reserves and in productive capacity of both gas and oil.

In 1967 we reached the point of less than self sufficiency in oil. And as you know, Mr. Chairman, over the years we have had a very nice margin of spare capacity. By 1985 we may triple our level of dependency.

There is a large gap between the potential of our resources and the projected performance of our domestic supplies. This means we have resource capability. But even were we to find and produce as much as half of the undiscovered oil estimated to remain in the United States, we would still need supplementary sources of liquid fuels well before the turn of the century.

Most of this increased supply from foreign sources must come from the Eastern Hemisphere, and more specifically, the oil exporting nations of Africa and the Middle East, which now hold about 80 percent of all the free foreign reserves of crude oil.

Even with the recent increases in foreign oil prices, oil from these sources is still cheaper than our domestic oil, and considerably cheaper than the cost estimates of the liquid fuels derived from the hydrocarbon sources of such things as coal and oil shale. But the important thing here is, how long can we expect this foreign oil to stay cheap, and will a dollar saved today cost us tenfold in future costs if we have a crippling denial, or if there are serious deficit trade balances.

The oil bloc today called the Organization of Petroleum Exporting Countries, or OPEC, comprises 11 nations. They produce 57 percent of the free world oil, and they control 83 percent of the reserves. They have the power to turn off and on at will this very vital resource. Whether they will or won't is anybody's guess, but just this last month, in July, at their 24th conference held in Austria, they made a very important resolution. This resolution is to take immediate steps toward government participation in the ownership of concession-holding companies. This we interpret as just another step toward ultimate nationalization. And just this last week Venezuela signed into law a nationalization bill, to take over the resources of that country.

I want to draw your attention as well to the posture of the NATO alliance. If we exclude the United States and Canada from this, the Alliance is 97 percent dependent on imported oil. And essentially all of that is from the OPEC bloc. Now, as the United States becomes more dependent on these sources—and these are the same sources—we would be competing for that same oil, and then the strongest link in this NATO chain weakens.

Over the years, too, Mr. Chairman, we have had a very comfortable level of spare refining capacity. Now there is a serious deficiency in both planned expansion of existing refineries as well as new refineries. And by 1975 we expect to reach the point on the incremental quantities of oil imports that products will have to be imported instead of crude oil, because we won't be able to refine the crude oil. We then face, Mr. Chairman, a situation of national double jeopardy, just as our east coast does today on residual fuel. We won't have the crude oil, and we won't have the refining capacity.

This situation can be attributed to two basic causes. One is the matter of siting. Companies cannot get sites today on which to build due to all the environmental concerns.

The other is uncertainty of future energy policy in general, and oil import policy in particular.

With regard to natural gas, the demand for gas in 1970 was 22 trillion cubic feet. By 1980 this will be 33 trillion cubic feet if we can get it. The level of proved reserves in the United States dropped from 1970 for the third successive year to 265 trillion cubic feet, excluding the North Slope of Alaska. This is 28 trillion cubic feet below the level at the end of 1967. The reserve-to-production ratio is currently about 12 to one. This is compared to 20 to one a decade ago.

Thus, Mr. Chairman, we also face an increasing dependence on imports of natural gas.

Now, this gloomy outlook for gas supply stands in vivid contrast to the estimates for the natural gas resources in the United States. For example, another 632 trillion cubic feet might be found in new provinces that are not now productive. The gas resources are here also, as well as the oil resources. The challenge is to find these resources in accumulations large enough and accessible enough to be attractive to investment in the domestic gas-producing ventures.

A few positive things have been happening very recently. The Federal Power Commission has authorized a few wellhead price increases. Approval has been given to import liquified natural gas from Algeria. There has been a stepped up leasing program of Federal lands announced by our Department, that is, the Department of Interior. And resolution of the Alaskan pipeline matter is getting closer.

With regard to emergency preparedness in oil and gas, I can report favorably on this. But this emergency preparedness, Mr. Chairman, as you know from the annual reports that we submit to your committee, is to manage and to utilize what we have in the best way we can. But the contingency plans and preparations can't perform miracles in getting these new supplies, because finding oil and gas and building pipelines and tankers and refineries take very long leadtimes. Our annual report which is coming up in the near future will give more details on our emergency preparedness program.

I have also indicated, Mr. Chairman, that we will send you a much more complete report on the refining situation.

And in my statement, as you have noticed, I have attached quite a number of charts.

Chairman PATMAN. And without objection we will put those in the record accompanying your testimony.

Mr. RICCA. Very good. And those all indicate what they mean, and they are good visual aids.

(The statement with attachments referred to follows:)

(The statement on U.S. petroleum refinery capacity and utilization begins on p. 197.)

STATEMENT OF MR. JOHN RICCA, ACTING DIRECTOR, OFFICE OF OIL AND GAS, DEPARTMENT OF THE INTERIOR

Mr. Chairman and members of the Committee, I appreciate the opportunity to appear before you today to discuss the Nation's oil and gas situation.

Oil and gas now supply over three-fourths of the energy requirements of the United States. Oil supplies about 43 percent and gas 33 percent. The energy consumption of the United States reflects our high industrial production and our high standard of living. Our problem for the future is how to meet growing energy requirements without dangerous dependence on imports.

In 1970 the United States consumed 14.7 million barrels a day of petroleum products. Of this total, 23 percent was imported. All projections indicate a steady rise in consumption of liquid fuels, so that by 1985 consumption will approach 27 million barrels a day, some 12 million barrels a day above the current rate.

Unless a marked and early improvement occurs in the development and movement of known oil such as Alaska North Slope and California, exploration and discovery success, recovery efficiency, and investment in oil producing activities in the United States, there is little chance that domestic production can keep up with this strong upward trend in demand. Thus, a steadily increasing share of the market must be supplied by imported oils or synthetic liquids produced domestically. By 1985 as much as 45 percent of our total oil supply may come from these sources, even with North Slope oil available.

For the past several years the levels of drilling and exploration maintained in the United States have not been able to prevent declines in both proved reserves and in productive capacity. Not only has exploratory effort fallen off, but also the amounts of oil discovered per foot of exploratory hole drilled have declined.

In 1967 the United States became less than self-sufficient in oil; that is, our imports are more than our unused productive capacity. In the past three years productive capacity has actually declined while both demand and production have risen, so that our dependence upon imported oil is currently increasing by about 750,000 barrels a day with each year that goes by. Before 1975 our expectation is that United States production, except for the North Slope, will be at effective capacity. Therefore, unless our domestic exploration and development is intensified, our reliance on imports will more than double to about 8 million barrels a day in 1980, and more than triple to 12 million barrels a day by 1985.

There is a large gap between the potential of our resources and the projected performance of our domestic oil supplies. Those who know the most about the occurrence of petroleum in the United States estimate that we have found less than half the amount of discoverable oil in the United States; specifically, that another 436 billion barrels await discovery, compared with the 388 billion barrels that had been found as of the end of 1968.

Even were we to find and produce as much as half the undiscovered oil estimated to remain in the United States, we would still need supplementary sources of liquid fuels well before the turn of the Century.

The fact remains, however, that imported oil is likely to be the principal supplementary source of liquid fuel available for many years. Limited expansion of present import levels can be expected from Canada and Venezuela, but these can be expected to fill only a small part of the growing demand. Accordingly, most of the increased supply from foreign sources must come from the Eastern Hemisphere, and specifically the oil exporting nations of Africa and the Middle East which hold 80 percent of all free foreign reserves of crude oil. Their supply base is ample; despite increases in production averaging 12 percent a year since 1960, the reserve-to-production ratio in that region in 1970 was 57 to 1—six times that of the United States. With the recent increases in foreign oil prices, oil from these sources is still cheaper than domestic oil, and considerably cheaper than cost estimates of the liquid fuels derived from other hydrocarbon sources such as coal and oil shale, but, how long can we expect it to stay so cheap and will a dollar saved today cost us tenfold in other future costs such as a crippling denial, deficit trade balances, etc.?

Today the Oil Bloc—Organization of Petroleum Exporting Countries comprise 11 nations producing 57 percent of the Free World's oil needs. They control 83 percent of the reserves. It was this Bloc that successfully imposed substantial oil price increases on Free World consumers. They have the power to turn off and on at will this vital resource. Whether they will or won't is anybody's guess, but a significant resolution came out of their XXIV conference held in Vienna, Austria on July 12 and 13. It is to take immediate steps toward government participation in the ownership of concession-holding companies. This is another step towards eventual complete nationalization. And, there was renewed interest shown in a joint production program that calls for oil curtailment to prevent price erosion. Also I want to draw to your attention the oil posture of the NATO Alliance as a whole. Because of our good position in 1970 and that of Canada, the Alliance was only 51 percent dependent on imported oil. If we exclude the United States and Canada from this, our Allies are 97 percent dependent. Essentially all of this is from the OPEC Bloc. As we become more dependent on the same sources, the strongest link in the chain weakens.

Over the years, too, Mr. Chairman, we have had a comfortable level of spare refining capacity, and while increased dependence on foreign oil is inevitable in the period between now and 1985, increased dependence on foreign refining is not inevitable, but is likely to occur if present trends are not quickly reversed. There is a serious deficiency in both planned expansion and new refineries. By 1975 at the latest we may reach the point that products must be imported instead of crude oil. We then face a situation of national double jeopardy, just as our East Coast does now on residual fuel oil. This situation can be attributed to two basic causes—one is sites—companies cannot get sites on which to build due to environmental concerns. The other is uncertainty of future energy policy in general, and oil import policy in particular. We are in the process of completing a detailed analysis of our refining situation and copies will be sent to your Committee.

NATURAL GAS

The demand for gas in 1970 was 22 trillion cubic feet. By 1980 we would use 33 trillion cubic feet if we could get it, or an average of 27.5 trillion cubic feet a year over this decade. Against this formidable requirement we have to note the following facts:

Our past five years' additions to proved reserves have averaged 15.2 trillion cubic feet a year. The best five-year period we ever experienced averaged less than 22 trillion cubic feet annually. The largest addition in any single year was 24.7 trillion cubic feet, in 1956.

The level of proved reserves of natural gas in the United States dropped in 1970 for the third successive year to 265 trillion cubic feet, excluding North Slope Alaska. This is 28 trillion cubic feet below the level at the end of 1967. The reserve-to-production index is currently about 12 to 1, compared with 20 to 1 in 1960. Natural gas transmission companies are desperately searching for new sources of supply and are turning down prospective customers. Even established customers are being denied additional service. There is the possibility of a widespread short fall of natural gas in a few years. While this will in all probability have little supply effect upon *existing* residential customers, prospective consumers of all types will have to look to other fuels, and existing industrial customers will be forced to transfer more and more of their demand to alternative sources of energy. Thus as in oil we face increasing dependence on imports of natural gas.

Liquefied natural gas is now imported in token amounts to cover peak-loading requirements of a few East Coast utilities. If all goes well with the current proposals for importing LNG in larger volumes, we might expect close to a trillion cubic feet from this source by 1975.

The Canadian National Energy Board has forecast that at most, Canada will be able to supply us with not more than 2.3 trillion cubic feet of gas in 1980. Last year Canadian gas supplied about 800 billion cubic feet, or only 3.5 percent of our total requirements.

This gloomy outlook for gas supply stands in vivid contrast to the estimates made by the most knowledgeable people in the business as to the occurrence and extent of the natural gas resources in the United States. The Potential Gas Committee, a group of esteemed scientists and engineers with many years of experience in their professions, has made a systematic, basin-by-basin survey of the natural gas resources of the United States. The Committee's estimate, from its findings, is that there is at least 260 trillion cubic feet of natural gas remaining to be discovered in known fields; that another 335 trillion cubic feet can be found in new fields within provinces that are now producing oil and gas; and that another 632 trillion cubic feet might be found in new provinces that are not now productive. The gas resources are here, apparently, in adequate volume to support all anticipated demand at least during the interval required to develop supplementary sources from coal. The challenge is to find them in accumulations large enough and accessible enough to be attractive to investment in domestic gas producing ventures. Mr. Chairman, the foregoing is a brief situation report with respect to oil and gas. A few positive things are happening:

The Federal Power Commission has authorized some well-head, price increases. Approval has been given to import LNG from Algeria. A stepped-up leasing program of Federal lands has been announced. Resolution of the Alaskan pipeline matter is getting closer.

With regard to emergency preparedness in oil and gas, I can report favorably for whatever consolation this may be. We have the mechanisms and the trained manpower to respond to a full spectrum of emergencies. But this is to manage and to utilize what we have in the best way we can. These contingency plans and preparations cannot perform miracles in getting new supplies. Finding oil and gas, building pipelines, tankers and refineries take long lead times. Our annual report to your Committee will give complete details on our emergency preparedness program. I have attached several charts and tables that graphically portray most of the situation as presented in the text—

1. *U.S. energy consumption in the 20th century.*—This reveals the dominant and vital roles of oil and gas.
2. *1970 U.S. dependency on oil imports.*—This reflects the situation in 1970.
3. *1985 U.S. dependency on oil imports* (with table).—The expected situation by 1985 if current trends continue.
4. *Crude oil and gas found per barrel per cubic feet produced, 1950–1970.*—This illustrates the rapid decline in finding rate since 1950.
5. *U.S. petroleum self-sufficiency, 1954–1975*—Here we can see how our strong petroleum surplus position has eroded to a deficit position today and will grow into the future.
6. *OPEC crude oil production and reserves, 1970.*—This reveals the dominant oil posture of the Organization of Petroleum Exporting Countries.
7. *Estimated supply and demand balance of NATO allies, 1970.*—This reflects the oil deficient position of the Alliance.
8. *Free world international flow of petroleum, 1970.*—This reflects the tremendous oil trade taking place and its logistic complexities.
9. *Spectrum of conflict.*—This chart reflects the method of response to various types of contingencies.

I shall be glad to answer any questions and submit additional facts for the record if desired.

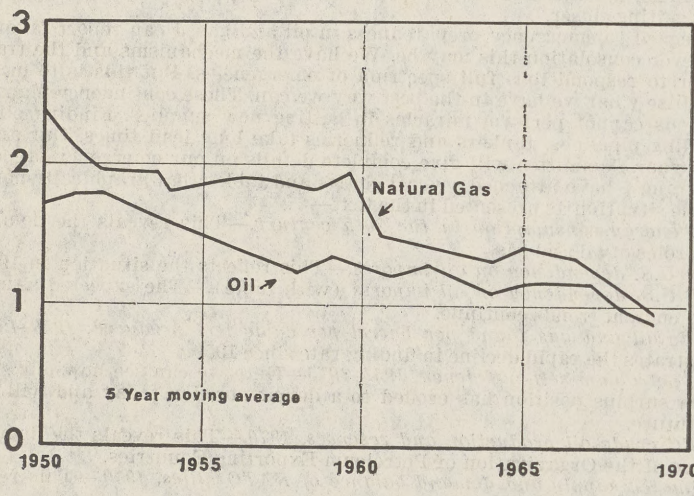
A PROJECTED U.S. PETROLEUM DEMAND/SUPPLY BALANCE, 1970–85

[In thousands of barrels daily]

	1970	1975	1980	1985
Domestic demand [1]	14,860	18,000	22,000	26,800
Exports	240	300	300	300
Total demand	15,100	18,300	22,300	27,100
Less—				
Processing gain	370	500	550	650
Stock reduction	20			
Required petroleum supplies	14,710	17,800	21,750	26,450
U.S. production: [2]				
Crude oil	9,600	11,200	11,900	12,600
Natural gas liquids	1,680	1,900	2,000	2,000
Total	11,280	13,100	13,900	14,600
Required from other sources	3,430	4,700	7,850	11,850
As percent of required supplies	23.3	26.4	36.1	44.8

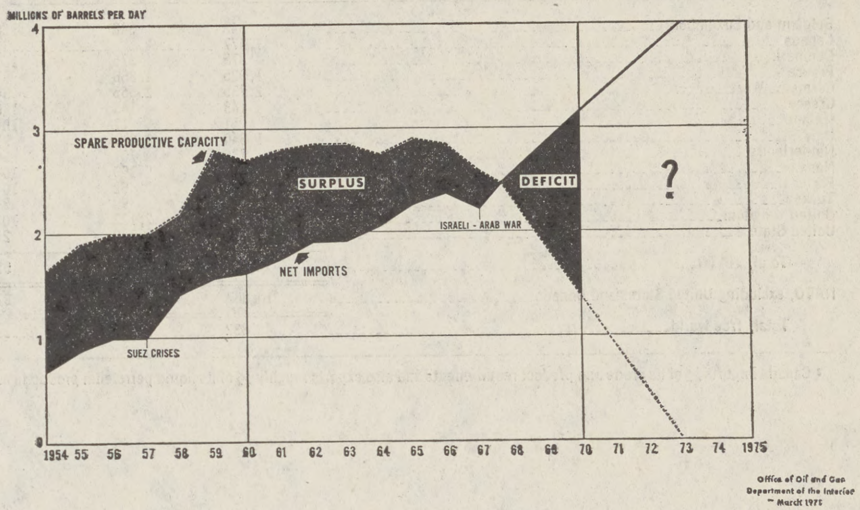
[1] Projected at a 4-percent annual growth rate. Neither demand nor imports include U.S. military offshore procurements.
[2] Assuming production at approximately present capacity, plus production from the North Slope of Alaska estimated at 500,000 barrels per day in 1975, 2,000,000 barrels per day in 1980, and 3,000,000 barrels per day by 1985.

CRUDE OIL AND GAS FOUND PER BARREL/ CUBIC FOOT PRODUCED



OOG March 1971

UNITED STATES PETROLEUM SELF SUFFICIENCY 1954-1975



ORGANIZATION OF PETROLEUM EXPORTING COUNTRIES CRUDE OIL PRODUCTION AND RESERVES—1970

Country	Crude oil production (thousand barrels daily)	Percent free world total production	Reserves Jan. 1, 1970 (million barrels)	Percent free world total reserves
Abu Dhabi	686	1.7	15,000	3.2
Algeria	990	2.5	8,025	1.7
Indonesia	854	2.1	18,000	3.9
Iran	3,848	9.8	55,000	11.8
Iraq	1,558	3.6	28,505	6.1
Kuwait	2,735	7.0	71,210	15.2
Libya	3,321	8.3	30,000	6.4
Nigeria	1,085	2.7	5,000	1.1
Qatar	361	1.0	3,900	1.0
Saudi Arabia	3,549	9.0	137,069	29.2
Venezuela	3,708	9.3	16,005	3.4
Total OPEC	22,695	57.0	387,714	83.0
Total free world	39,912	100.0	467,283	100.0

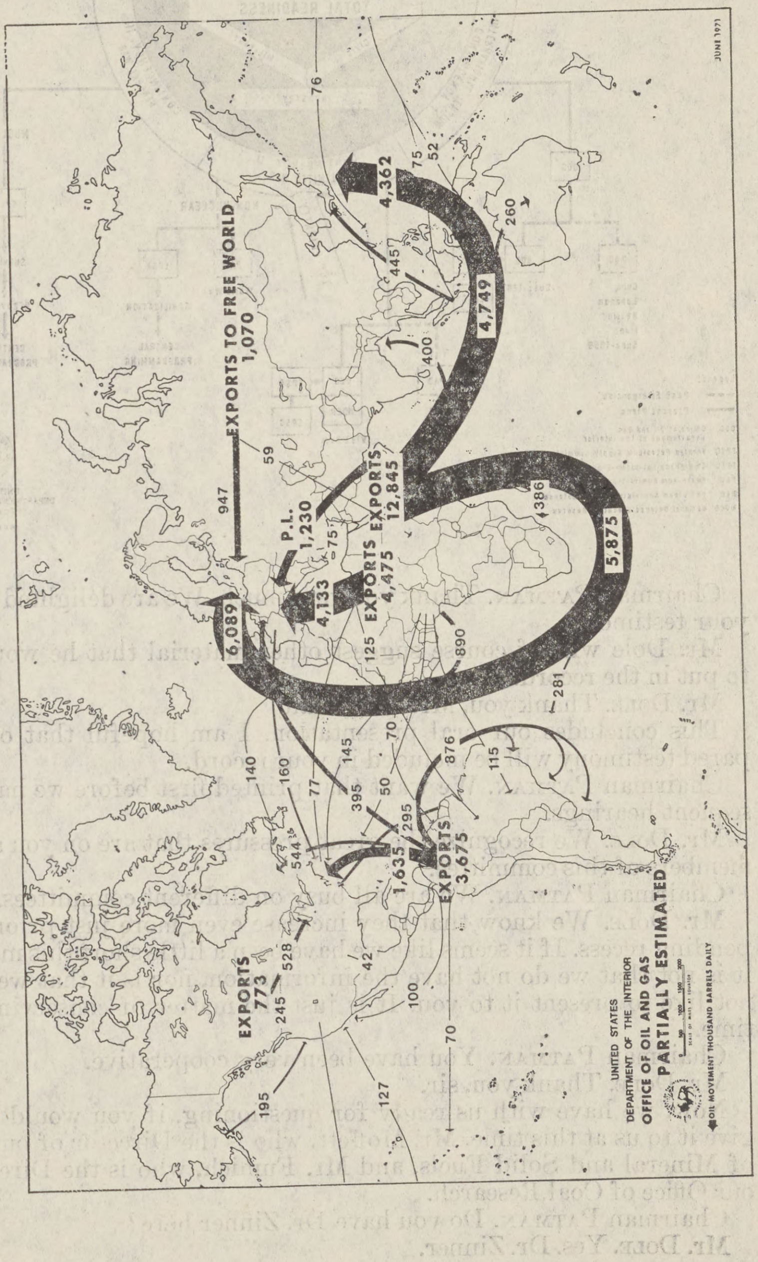
ESTIMATED SUPPLY AND DEMAND BALANCE NATO ALLIES—1970

[In thousands of barrels daily]

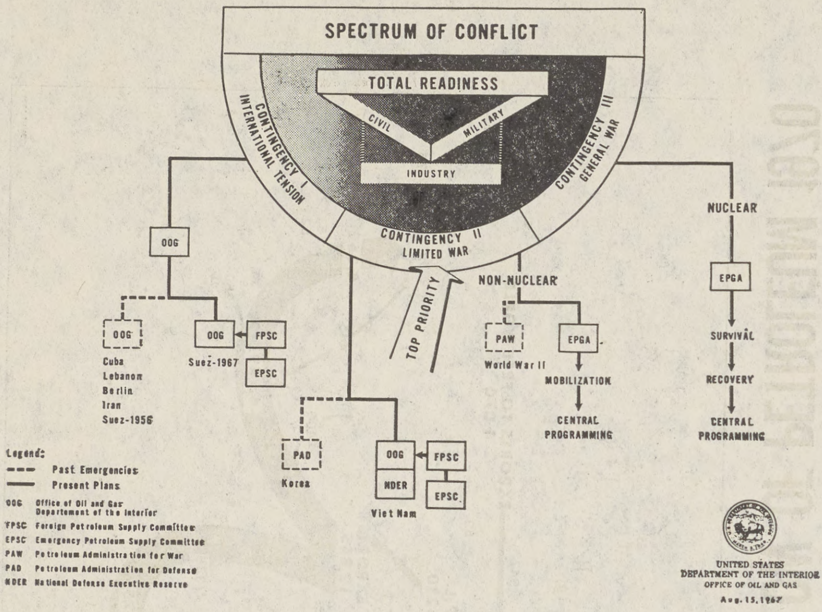
Country	Crude and product demand	Net imports required	Percent dependence on imports
Belgium and Luxembourg	548	548	100
Canada [1]	1,477		
Denmark	375	375	100
France	1,925	1,866	97
Germany, West	2,735	2,565	94
Greece	143	143	100
Iceland	11	11	100
Italy	1,840	1,810	98
Netherlands	738	701	95
Norway	169	169	100
Portugal	92	92	100
Turkey	162	90	56
United Kingdom	2,125	2,122	100
United States	14,367	3,036	21
Total, NATO	26,707	13,528	51
NATO, excluding United States and Canada	10,863	10,492	97
Total, free world	40,832		

[1] Canada imports ½ of its crude and product requirements and also exports roughly ½ of its liquid petroleum production.

FREE WORLD INTERNATIONAL FLOW OF PETROLEUM 1970



ANTICIPATED EPGA INVOLVEMENT IN EMERGENCY SITUATIONS



Chairman PATMAN. Thank you very much. We are delighted to have your testimony.

Mr. Dole will of course suggest other material that he would like to put in the record.

Mr. DOLE. Thank you, Mr. Chairman.

This concludes our oral presentation. I am hopeful that our prepared testimony will be included in your record.

Chairman PATMAN. We want that printed first before we have subsequent hearings.

Mr. DOLE. We recognize the great pressures that are on you and the members of this committee.

Chairman PATMAN. We are all busy on different committees.

Mr. DOLE. We know that they increase even more just prior to the pending recess. If it seems like we have been a little short this morning, it is not that we do not have the information, nor is it that we would not like to present it to you. It is just the matter of conserving your time.

Chairman PATMAN. You have been very cooperative.

Mr. DOLE. Thank you, sir.

Now, we have with us ready for questioning, if you would care to give it to us at this time, Mr. Moffett, who is the Director of our Office of Mineral and Solid Fuels, and Mr. Fumich, who is the Director of our Office of Coal Research.

Chairman PATMAN. Do you have Dr. Zinner here?

Mr. DOLE. Yes. Dr. Zinner.

Chairman PATMAN. Dr. Zinner, I am told by the director of the staff, Mr. Warren, that you could summarize the chart and tell us how your staff makes forecasts. If you will prepare that for the record and insert it at this point—what we are anxious to do is have this record printed up first before we question you. We can do it more intelligently and certainly with more knowledge after that is done.

Dr. ZINNER. We will be delighted to do that.

Chairman PATMAN. If you will go into that as fully as you think you should in order to give us the information about how you prepare the charts and how you make the forecasts it will be appreciated.

Dr. ZINNER. Yes, sir; we would be glad to do that.

(The statement of Dr. Zinner, Assistant Director for Planning, Bureau of Mines, begins on p. 217.)

Chairman PATMAN. Would the other gentlemen like to prepare a statement and put it in this record, Mr. Dole? You see, this record is important.

Mr. DOLE. Yes, sir.

Chairman PATMAN. It will be printed and available when we have subsequent hearings.

Mr. DOLE. Yes. Both Mr. Moffett and Mr. Fumich will prepare a statement for the record.

Chairman PATMAN. That will be fine.

(The statement of Mr. Harry L. Moffett, Director of the Office of Minerals and Solid Fuels, begins on p. 56.)

(The statement of Mr. George Fumich, Jr., Director, Office of Coal Research, begins on p. 58.)

Chairman PATMAN. Do you know of anything else that we ought to put in the record this morning?

Mr. DOLE. I think, Mr. Chairman, when you get all the information that we will make available to you for your consideration of this most important subject of our national minerals posture, particularly in relation to our national security, that you will be very happy with it.

Chairman PATMAN. Don't you have a person here with expertise on coal research?

Mr. DOLE. Yes; this is Mr. Fumich, director of our Office of Coal Research.

Chairman PATMAN. Let us have his statement, too. That will be fine. (See p. 58.)

And we would like to have you gentlemen with us at the next meeting, and we will have questions by the committee. It is almost impossible to ask all of these questions orally. We will prepare them in writing and submit them to you and the different witnesses and ask you to answer them.

Mr. DOLE. Fine, Mr. Chairman.

I would also call your attention to the fact that when Congress passed the Mining and Minerals Policy Act of 1970, it required that the Secretary of Interior report to the Congress annually on the state of the domestic mining, minerals, and minerals reclamation industries. I think that the statement he will submit to Congress each year will be of great interest to you and this committee.

Chairman PATMAN. Was it submitted last January?

Mr. DOLE. No, sir; this bill passed, I believe it was December 31, 1970.

Chairman PATMAN. In other words, the first report will be in January of next year?

Mr. DOLE. Yes, sir; early in January of 1972.

Chairman PATMAN. And you furnish the report to each member of our committee and have some for the staff of the committee if you please.

Mr. DOLE. We certainly will.

Chairman PATMAN. When do you think that will be released? Will it be released before January?

Mr. DOLE. Mr. Chairman, this is a formidable job which we have been assigned, and one which we welcome. And in gearing up for this—as Dr. Osborn noted, a special office within the Bureau of Mines has been established to develop data on which to base our report. As Mr. Radlinski noted, he has also set up a similar group within the Geological Survey. This is also true in the Office of Oil and Gas. And Mr. Moffett, the Director of the Office of Minerals and Solid Fuels, is coordinating this whole setup on my behalf. We hope to have a general report ready by January 1, 1972. And we hope following that to be able to submit to Congress suggestions for needed policy legislation. This initial report probably will not be in as great depth as we might like to see it due to the shortness of time for its preparation. But I assure you that in the years to come we will expand upon it.

Chairman PATMAN. Wonderful. Let's disassociate it from this particular hearing.

Mr. DOLE. Yes; I think it should be.

Chairman PATMAN. And we will have that later on. But we must get out our report at least by October or November.

Before we close up here this morning would any of you gentlemen like to make any statement or comments?

Mr. Barrett.

Mr. BARRETT. Mr. Chairman, I would like to ask Mr. Dole one question.

You indicate that aluminum is going to be in very scarce supply. You anticipate the number of years that it might last.

Back in 1942 we built an all aluminum home with aluminum extrusions, locks, the roof, and everything was extruded, and locked in right on the site. And the interior was all aluminum and no paint. And there is now popping up some questions about some of the construction industry going into aluminum homes. Do you anticipate the supply being that short, that that would not be possible?

Mr. DOLE. Mr. Barrett, I think Dr. Osborn, in replying to the chairman's question on what minerals or materials could possibly be in short supply as regards national security, used aluminum as an example. Aluminum—like nickel, we import about 90 percent of our basic material, either in the form of alumina or as bauxite. All the rest of the materials are found in overseas areas—for instance in Jamaica, Guyana, Surinam, Australia, and elsewhere. As I noted in my statement, the reliance of countries upon their basic raw materials as a source of employment is becoming greater, with the net result that they are requiring more of the material to be processed to higher useable forms at home than in the past.

There is always the possibility, when you are depending upon such a basic material as aluminum, that countries will demand either a higher price or greater processing of that material within the country of origin, taking that labor away from our country and increasing the price.

So I believe, in answer to your question, there is no shortage of aluminum basic materials in the world today. And if this were a world in which peace was present at all times and we had ready exchange between all countries, there would be no reason for concern. But unfortunately civilization has not progressed to that point today.

Mr. BARRETT. Just one further question. What is the aluminum stockpile today?

Mr. DOLE. Mr. Moffett, will you please respond.

Mr. MOFFETT. It is fairly sizable. There are 1,275,000 short tons in the stockpile. The stockpile objective is 450,000 short tons and the excess in the stockpile over the objective is committed for sale under long term contracts.

Dr. OSBORN. Mr. Chairman, may I just make one additional remark.

Chairman PATMAN. Certainly.

Dr. OSBORN. Lower grade aluminum resources, ores, are very abundant in this country, but they are much lower grade.

Mr. DOLE. They are different types of materials. Whereas we consider the main source of aluminum from imported bauxite, which is aluminum oxide, we have abundant resources of high aluminum clays, aluminum silicates, in the United States. Also there are aluminum minerals in the oil shales, and also we have the lower grade bauxite such as the ferruginous bauxite of the Northwest. So again, like in the energy materials, it is not a shortage of aluminum materials, but it is the change in the pattern of regular usage.

Mr. BARRETT. That answers it.

Chairman PATMAN. Mr. Barrett is satisfied.

Mr. Widnall, would you like to ask any questions?

Mr. WIDNALL. Thank you, Mr. Chairman.

I wasn't here, as you know, to listen to all the statements. And we are certainly not going to go at this time into a thorough and exhaustive questioning based on those statements and other material you furnished to the committee.

I am interested particularly in the situation with respect to petroleum. And this is one of the most immediate concerns. We are feeling the effects of the shortage, as I understand it. I don't understand yet, from a quick look at the charts here, whether it is a shortage of capacity, of reserves, or just a shutting off of some of the sources that we have had before. What is the principal problem causing the deficit right now, the shutting off of Mid East petroleum supplies?

Mr. DOLE. Mr. Widnall, as Mr. Ricca, from our Office of Oil and Gas, mentioned, our capability of producing all of our own petroleum resources has diminished now to the point where we no longer have sufficient shut-in capacity to offset total imports. If you will recall, back a few years ago whenever we had a shut-off or a curtailment of overseas supplies, we were able to increase the production internally to fulfill, not only our full requirements, but some of our allies. Our ratio of finding oil to using oil and gas has been decreasing over the years, until now that reliance that we have on overseas resources is felt immediately when this reliance is diminished. We went through that just this past year when the amount of oil coming from Lybia was reduced. And as you know, the Suez Canal is cut off, and the Trans-Arab pipeline was stopped, with the net result that sources of oil coming from the Persian Gulf had to go around Africa to get here. This increased the demands upon transportation, resulting in increased transportation costs, and a serious question as to whether we had the capability of getting all the petroleum supplies that we needed.

Now, as regards the refining capacity, if you will recall, a few years back, about 1966, we removed import restrictions of residual oil on the east coast in Region 1, it is called. The net result of this was that the residual fuel oil, which is the major source of energy for power generators on the east coast, became entirely reliant upon the imported material. The secondary result of that was that we exported in effect our residual refining capacity overseas. So the two things, the lack of reserves in our country, and the increasing dependence upon foreign supply, with their controlling either the price or the transportation cost, caused an increase in the cost of residual fuel on the east coast.

I don't believe that we have ever had a shortage of fuel materials. We have been close to it, but we have never had a shortage of fuel materials on the east coast. But we have had problems regarding prices.

Mr. Widnall. It seems to me as a Member of Congress that for years we have had demands on us to open up the importation of residual oil supplies. And the problem didn't address itself so much to the present conditions of the world so much, but rather the people were interested in getting the oil from overseas at a more favorable price. Now, that has taken place, and conditions changed here in this country so that we are not getting the advantage of a lower price.

Mr. Dole. Mr. Widnall, I think this is a very appropriate committee in which to study this particular subject. As mentioned earlier, our reserve producing capacity in the United States has diminished practically to point zero. Our demands for fuel are increasing at a very great rate, with the net result that we are becoming more and more dependent upon overseas sources of supply. Some of these overseas sources of supply are not very secure. Therefore transportation plays a very important part on it, depending upon the availability of tankers. Not only does transportation play an important part on the cost, but when a country decides, as Lybia did, to cut back on their production, then it makes the rest of the countries produce more, and the material becomes more dear. So you have several things involved when you put heavy reliance of energy on imported oil as you have done on the east coast. We no longer have the spare supply in our own producing sources. In other words, our sources do not provide the security they once did.

Mr. Widnall. The problem of getting into other sources of new energy is that we have this tremendous attack going on throughout the United States with the aim of environmental protection. And this is against nuclear energy, and strip mining, and one combined with the other certainly pushes for higher pricing one way or the other, isn't that so?

Mr. Dole. I don't believe there is any question, Mr. Widnall, but what this is true. In other words, what we are saying is that we have been charging the cost of a good many of those materials off against the environment. And now we are going to go to the principle of full cost accounting in which we feel that in the Bureau of Mines that we must add a third element to the mining process. Not only do we have to find it and take it out, but we have to put that land back for further use. This is going to add to the cost. We are going to have to extract the sulfur from the smelters stack gases and from the coal burning power generating gases. This is going to add to the cost. In other words, this country of ours is awakening to the fact that environment does have a price to pay. We have not been paying it in the past, and we will pay it in the future.

Mr. WIDNALL. Thank you. That is all.

Chairman PATMAN. Mr. Brown.

Mr. BROWN. Mr. Dole, in your projections of the needs and resources and so on, to what extent have you considered the use of nuclear power as a replacement for the traditional energy resources of coal, oil, and gas, and so on?

Mr. DOLE. We have depended, Mr. Brown, a great deal on the projections by the Atomic Energy Commission. As you know, right now atomic power supplies less than 1 percent of our energy needs today. And by 1985 it is going to be around 15 percent; and in the year 2000, perhaps as much as 25 percent.

Mr. BROWN. What I am asking, in your projected needs for oil, gas, et cetera, you have, then, considered the increasing potential of nuclear?

Mr. DOLE. Very definitely. And I would point out, Mr. Brown, that even though we are going to become more and more reliant on nuclear generation of power, that our demands for energy in the future are going to be so great that the quantity of other energy materials we are going to need is going to have to increase too, and at a very rapid rate.

I would also point out that nuclear power does not take into consideration the energy requirement of transportation, for instance, the airplane, the car, and the like. It has its greatest impact within the electrical generating area.

Mr. BROWN. That was going to be my next question. Is there a wipe-out point as far as nuclear power being able to replace the traditional resources? You say it is going from 1 percent now to 10 percent, and so on. Is there a point you reach where you have about the full capacity for replacement or for supplanting of traditional resources?

Mr. DOLE. I suppose this would be, Mr. Brown, but I can't give it to you, and it would be quite a ways into the future. I would be glad to have this question addressed by some of the experts in the Bureau.

Mr. BROWN. Because we all recognize, I think, that there are certain energy needs that cannot be supplied.

Chairman PATMAN. Mr. Brown, will it be satisfactory now to have him prepare it and insert it in the record?

Mr. DOLE. In Mr. Ricca's testimony, Mr. Brown, one chart was submitted on U.S. energy consumption to the 20th century. And it shows there that by the year 2000 that nuclear will be giving 22.7 percent of our energy needs.

Chairman PATMAN. At this point we will not ask you to project your information beyond the year 2000, but give it consideration. But I think in the future you will.

Mr. Dole. Thank you, Mr. Chairman.

This is a most difficult thing, to look into your crystal ball, the further you look into the future the cloudier it gets. Now, if you will recall, when the Paley Commission report was made back in 1952, it stated our energy and mineral needs would be such and such by the year 1970. In practically every instance we had exceeded those estimates by the year 1965. Yet we are looking from 1952 to 1970, a time period of 18 years, and the estimates were off 50 to 100 percent. And yet at that time those were the best estimates by the best brains here in our country. So when you look beyond the year 2000, when you look 10 to 15 years ahead, the picture becomes cloudier and cloudier. But we will do our best.

Chairman Patman. Any other questions, Mr. Brown.

Mr. Brown. Just one more, if I may, Mr. Chairman.

In the discussion of the increase in production of coal by the U.S.S.R., I think we talked about price, costs, and things of this nature. To what extent does Russia have safety requirements, environmental requirements, and so on, that are imposed upon the production of coal, for instance, in this country, and to what extent is there a difference in cost factor there?

Mr. Dole. Mr. Brown, we had a coal mission to Russia about a year ago. And the question as to costs arose. It is almost impossible for us to figure out the costs of production of coal in Russia and I think it is almost impossible for them to fully determine their costs. I have recently returned from a visit to western Siberia, made in the latter part of June of this year, in which we looked at two of their large oil fields, the Samotlor was the one in which they expect a great deal of production from in the next 5 years. And I will say this, that their concern for the environment certainly does not approach our concern for the environment. As a matter of fact, in discussing this subject with them we detected that they felt that we were trying to hide something by directing our concern to the environment. But I think I can tell you that in the opening up of the Hamotloc field, which I observed, we here in this country could not and would not have developed it in the same manner in which they are doing it.

In essence what I am saying is that even though they are concerned for air pollution, for instance, in Moscow itself, where there are no coal or oil generating plants—they are all gas—but out in the vast lands of western Siberia, and away from the metropolitan areas, it did not appear to us that their concern for the environment approached our concern. And so it would not be brought into the cost.

Mr. Brown. Thank you.

Chairman Patman. Any other comments or questions?

Mr. Barrett. Yes.

Getting back to the mining of coal. You said there is the additional cost of having to replace the extraction, and that becomes costly. Isn't it true that some of these people pay you to permit them to fill these mine strips, and you wouldn't have to——

Mr. Dole. I don't think I understand your question, Mr. Barrett. But let me try and answer it this way.

As you know, the administration has introduced a mine land reclamation bill, on which I understand the House Interior Committee will be having hearings beginning September 20. And as you also know, the States throughout the Union are passing more and more stringent mine land reclamation bills. I believe right now the number is nearing 30—do you recall Mr. Zinner.

Mr. ZINNER. I don't believe it is quite that high, although the number is increasing rapidly. I think it is about 25.

Mr. DOLE. And this compares with States having mine land reclamation laws of around 8 or 10, 2 or 3 years ago. And furthermore, they are becoming tougher and tougher, as they should be. Because of the difference in topography, in climate, in vegetation, the Federal Government—the administration, in its mine land reclamation proposal, is putting the major responsibility of this on the States. And similar to the Air and Water Quality Act, the Department of Interior would be responsible for setting up minimum requirements. Where States did not meet these, then and only then would the Federal Government step in.

I am not sure that I answered your question the way you wanted it, but that is an attempt.

Mr. BARRETT. I think you did in some respects. But I was thinking that you were adding an additional expense to mining when you strip the mine you have to replace. And that is costly.

Mr. DOLE. Yes.

Mr. BARRETT. My question is: Because of the environment, because of pollution now, they cannot find places where they can dispose of the rubble of the cities, et cetera. The mines could be used for that purpose. Those who are contracting to dispose of the rubble from cities are looking for places to dispose of it. They will even pay to be permitted to put their rubble, compacted, into the strip mines, rather than you paying or paying to have them refilled.

Mr. DOLE. Mr. Barrett, I would like to respond to that question. No. 1, when I said that we were adding a third element to mining, in the past, as you know, mining—and I am a mining engineer—was made up of two parts. First, finding the ore, and then getting it out. We feel that the third element, returning this land for future use, is an essential. Now, that is what I meant there.

Now, as far as having strip-mined areas for the repository of urban wastes, we feel that these urban wastes are too valuable to be used in this way——

Mr. BARRETT. May I interpose and say here that only recently the urban wastes became valuable as fertile soil. Just recently through new developments, and technology. The point I am making here is, isn't it true that they will pay you for refilling the strip mines, rather than you pay them?

Mr. DOLE. Mr. Barrett, I think this is in removing refuse from the city in order to get rid of it. But as I mentioned I think that this is too valuable to throw away with its contained minerals and other materials. I do not think we are any longer in a position where we can afford to dispose of them entirely. I think we should recycle them and reclaim what we can from them. And this way we will make that, instead of a burden, an added attraction.

Mr. BARRETT. That is all, Mr. Chairman.

Chairman PATMAN. On that last point, Mr. Dole, have there been any studies, any statistics developed, with respect to the extent to which many of these minerals can be recovered, to what extent recycling can furnish the needs of the country in the future? I realize that cost is a big item there.

Mr. DOLE. Yes, cost certainly is a big item. But I go back to an earlier statement I made, to the effect that we have been charging many of the costs of these materials off against the environment, and this is no longer acceptable. And so therefore they become—these so called waste materials do become closer to being economic. Now, as to the amounts that they could furnish, I think some of these charts that Dr. Osborn submitted to you indicate that there is a lot of recycling right now. I think better than 20 to 30 percent of the copper, better than 40 percent of the zinc and the lead, and a large percentage, I think it is something like 30 percent of the iron, is being put back into commerce. I am not sure of the complete accuracy of my figures there, but they are in the ball park.

As to the possibility of what these materials might furnish in the future, I think that we have made some studies on this, have we not, Mr. Zinner.

Mr. ZINNER. That is correct, particularly in the urban waste sector.

Mr. DOLE. In the contribution that they might make to future mineral supplies.

Dr. OSBORN. Could I comment, Mr. Chairman, on this point.

Chairman PATMAN. Certainly.

Dr. OSBORN. In the reports on our urban wastes research that were placed in the record earlier, there are some numbers which I think are what you are asking about. Very briefly, in the collection of urban wastes the cost is about $18 a ton on an average across the country, just for the collection. The disposal cost is about another $5 a ton. They have got to bury it somewhere, or burn it or something. Now, we can reprocess this same material in our pilot plant at a cost of about $3 a ton——

Mr. BROWN. What are you talking about, iron?

Dr. OSBORN. No, all the urban wastes, the trash that is collected by the trash collector, the garbage, and so on. This is fed into an incinerator in some of the cities—not all of them. In Alexandria, Va., for example, it is fed into the incinerator and their total cost will be $23 a ton, to collect, incinerate and get rid of the residue. In our pilot plant we take this incinerator residue and instead of having it buried at a cost, we process it at a cost of about $3 a ton and produce materials now worth about $15 a ton. We even separate the colored glass from the uncolored glass because of the difference in price, and separate aluminum from iron, and so on, with a saving therefore of about $12 a ton. So this process will reduce the cost of disposal from an average of about $23 a ton of urban wastes to about $11 a ton to collect and dispose of urban wastes, and in addition put valuable materials back into circulation.

Mr. BARRETT. Mr. Dole, may I interpose.

Mr. DOLE. Yes, Mr. Barrett.

Mr. BARRETT. Let me say this. The treatment they have now is a cold chemical treatment, and there is no incineration at all needed. They press these into logs.

Mr. DOLE. Yes.

Dr. OSBORN. That is the difference in the case.

Mr. BARRETT. And then they take the logs and lay them in an area where it ultimately becomes good fertile soil for farming.

Mr. DOLE. Yes.

Mr. WIDNALL. Will the gentleman yield.

When you reclaim a strip mine what do you do? How do you go about reclaiming it?

Mr. DOLE. Let me give you an example, Mr. Widnall. This is an example that I am aware of in Wyoming. They will first remove the topsoil, providing the topsoil is greater than 6 inches in depth. With less than that they have difficulty. They will stockpile it. After they have removed the overburden, mined out the coal, then they overcast back, continually moving over. And they will take a bulldozer and conform the surface to a condition of the topography similar to that which was present prior to mining, replace the soil, plant it with range grass, and continue on.

This type of reclamation probably has developed to its highest degree in the brown coal deposits of Germany, where whole cities are replaced after they have been moved out to mine the area. After the mining is done they will put the soil back in and they will give you the type of topography you want, with lakes or hills or whatever it is, and move the cities back in. And this is what I mean by adding the third element to mining, to put the land back for further use. So in this instance, then, mining becomes a temporary use of the land.

Mr. WIDNALL. Thank you.

Chairman PATMAN. The committee this morning, of course, was handicapped by not having the Members of the U.S. Senate here, but they just couldn't come this morning. They have a bill coming up this afternoon known as the Lockheed bill.

Mr. DOLE. I have read about it.

Chairman PATMAN. That occupied our time and attention for many weeks. And it is very important today, because the Senate will vote about 3 o'clock on it, up or down, and Senator Sparkman, vice chairman, could not come because he is presiding over his own committee. But he sent his Administrative Assistant, Mr. Robert Locklin, over to this hearing. And Senator Proxmire, I talked to him, and he was unable to come for the same reason. But he has an observer here. And we have had practically all the members represented here this morning, one way or the other, in fact all the House Members have been here.

And we certainly appreciate the interest manifested by you, Mr. Dole, and your associates. You have really thrilled us. And if all the members feel like I do about it, we are going into this in depth and try to produce a record of which we will all be proud. And thank you, gentlemen, very much for coming.

And we will recess now, subject to the call of the Chair. And we will consult you before we have another hearing.

Mr. DOLE. Thank you, Mr. Chairman.

(Whereupon, at 11:50 a.m., the committee adjourned, subject to the call of the Chair.)

(The following additional statements and information was subsequently received for the record:)

STATEMENT OF HARRY L. MOFFETT, DIRECTOR, OFFICE OF MINERALS AND SOLID FUELS, DEPARTMENT OF THE INTERIOR

Mr. Chairman and members of this Committee, I appreciate the opportunity to present this statement to you.

Secretary Dole has already covered much of the ground on which our statement can be based and I shall not repeat his assessment of our overall minerals posture. He has pointed up the fact that we cannot fulfill all of our mineral requirements from domestic sources and emphasized the importance of an adequate and reliable supply of essential minerals and fuels to our national security. It is in this area that the Office of Minerals and Solid Fuels has most immediate concern. Also the statements of Dr. Osborn, Mr. Radlinski, and Mr. Ricca have outlined in detail many of the areas in which our office is also involved and there is no need to repeat them.

As this committee knows, the Secretary of Interior, under provisions of Executive Order 11490, is charged with the responsibility for insuring an adequate supply of metals, minerals and solid fuels to meet the requirements of national security. Under the direct supervision of the Assistant Secretary of Interior for Mineral Resources, the Office of Minerals and Solid Fuels directs its efforts to providing Departmental attention to the problems of the solid fuels, metals and mineral industries and to acting as a focal point for these industries to present and have considered important problems involving Government policy. It provides staff assistance to the Secretary on minerals and fuels policy matters and assists in the development of plans and programs for the maintenance of an adequate supply of mineral raw materials to meet essential civilian and military requirements under partial or full mobilization. This includes the development, assembly, and evaluation of data on materials, equipment, manpower, transportation, electric power and other requirements of the minerals and solid fuels industries that would be experienced during a national emergency. In addition, in order to provide for continuity of production and distribution during an emergency, the Office maintains standby orders, regulations, and plans to provide for a state of readiness for all conditions of national emergency in collaboration with other Federal, State and local governments.

In carrying out the Secretary's responsibility under Executive Order 11490, this Office has devoted a major portion of the time in preparing national emergency plans, developing preparedness programs and attaining an appropriate state of readiness with respect to functions assigned under this Order for all conditions of national emergency. As an emergency preparedness measure the Secretary has established in standby the Emergency Minerals Administration and the Emergency Solid Fuels Administration. The Department has designated highly qualified people from the domestic minerals producing industry, academic institutions and labor unions as members of the National Defense Executive Reserve and Departmental employees to serve in key positions of these two emergency agencies.

One of our major roles is participation, in an advisory role, in stockpile activities. We do not have any direct authority for stockpile management but we assist and advise the Office of Emergency Preparedness in developing data for determining stockpile objectives. The Office coordinates the Department's activities in compiling mineral supply data and evaluating the state of the minerals industry for setting stockpile objectives and purchase and procurement programs. We also assist the Office of Emergency Preparedness and the General Services Administration in the development of programs for the disposal of excess stockpile materials to assure orderly marketing without disruption to the mineral industries. During the development of the various stockpile programs the Office consults with the domestic minerals industry regarding the impact of the programs.

As part of this responsibility for assuring mineral supply necessary for national security the Office is now updating and preparing mobilization base studies on 41 metal and mineral commodities. On the basis of these studies the Office is prepared to recommend and assist in programs to protect or expand in peacetime the domestic production capacity. We also are involved in various defense-related problems of concern to the Department such as shortages, export controls and import controls. The Department's annual report to this committee contains a recitation of our activities in these areas and as you know, the next such report will be in your hands shortly.

It should be pointed out that our stockpile of strategic and critical materials provides a strong base to assure availability of needed materials in time of national emergency. These inventories are not only a supply of raw and essential materials but represent huge savings in manpower and production that would be necessary were they not in being. They also lessen the reliance on foreign sources of supply in the early stages of any emergency.

As Secretary Dole has told you we are not affluent in all mineral raw materials. Thus we must assess our overall mineral position and arrive at courses of action which will maintain a strong and stable domestic minerals production base wherever possible while at the same time strengthening our minerals position abroad to the end that we have assured sources of supply to meet our deficiencies.

Attached is a table indicating the extent of our reliance on imports for selected strategic minerals, which we believe you will find of interest. This points up the necessity for not only encouraging further development of any of these minerals that could possibly come from domestic sources but also to the furtherance of programs which would recycle used mineral commodities into the production stream in major quantities.

The Mining and Minerals Policy Act of 1970, enacted last December, imposes upon the Secretary of Interior the responsibility for reporting annually upon the state of the domestic mining, minerals and minerals reclamation industries and for making recommendations as to policies needed to encourage free enterprise development of domestic mineral (including fuels) resources. Task forces within the U.S. Bureau of Mines, U.S. Geological Survey, and the Office of Oil and Gas are identifying our minerals position, delineating major problem areas, and pointing up needs for action to overcome deficiencies. The Office of Minerals and Solid Fuels has the task of coordinating these efforts and developing the first report of the Secretary of Interior, due early next year. This Committee has expressed its interest in these activities and as Secretary Dole has emphasized, we appreciate that interest and shall see that copies of this report are made available to you when it is issued.

Thank you for the opportunity to present this brief statement.

LIST OF SELECTED MINERALS AND METALS SHOWING U.S. DEPENDENCY ON FOREIGN SOURCES IN CALENDAR 1970

[Percent of U.S. consumption from foreign sources]

Commodity	Total	By source	Quantity of net imports
Aluminum	91	Jamaica 41, Surinam 16, Australia 11, Canada 6, Dominican Republic 4, Guyana 3, Haiti 3, other 7.	4,382,000 tons.
Antimony	94	Republic of South Africa 32, Mexico 20, United Kingdom 14, Bolivia 11, Guatemala 6, France 4, other 7.	18,100 tons.
Asbestos	83	Canada 78, Republic of South Africa 3, other 2	649,400 tons.
Beryllium (ore)	51	Brazil 37, Uganda 4, Republic of South Africa 3, Argentina 3, Mozambique 2, other 2.	4,940 tons.
Cadmium	53	Canada 17, Mexico 16, Japan 7, other 13	3,460 tons.
Chromite	100	U.S.S.R. 33, Republic of South Africa 29, Turkey 18, Philippines 15, other 5.	1,405,000 tons.
Cobalt	93	Congo (Kinshasa) 52, Belgium-Luxembourg 26, Norway 6, Canada 3, other 6.	6,200 tons.
Columbium	100	Brazil 58, Canada 22, Nigeria 12, Congo (Kinshasa) 2; Angola, Argentina, Belgium-Luxembourg, Burundi-Rwanda, West Germany, Mozambique, Portugal, Singapore, Uganda, United Kingdom 4.	2,860 tons.
Copper	6	Peru 2, Chile 2, Canada 1, other 1	9,900 tons.
Fluorspar	78	Mexico 60, Spain 10, Italy 6, United Kingdom, Brazil, Mozambique, West Germany, Republic of South Africa 2.	1,077,000 tons.
Iron ore	33	Canada 18, Venezuela 10, Australia, Brazil, Chile, Liberia, Peru, Sweden 5.	39,400,000 tons.
Lead	38	Canada 11, Australia 9, Peru 8, Mexico 4, Yugoslavia 2, Honduras 1, other 3.	350,000 tons.
Magnesium	0		(31,200) tons.
Manganese (plus 35% ore).	99	Brazil 35, Gabon 31, Republic of South Africa 8, India 4, Ghana 4, other 17.	836,600 tons.
Mercury	38	Canada 31, Spain 3, other 4	17,000 flasks, of 76 pounds each.
Mica	100	India 86, Brazil 13, other 1	5,309,000 pounds.
Molybdenum	0		(55,737,000) pounds.
Nickel	87	Canada 72, Norway 7, Republic of South Africa 1, other 7	135,000 tons.
Platinum-group metals	98	United Kingdom 45, U.S.S.R. 34, Republic of South Africa 8, Japan 3, Canada 2, Colombia 2, Belgium-Luxembourg 1, Norway 1, other 2.	1,009,300 ounces.
Rhenium	7	West Germany 3, U.S.S.R. 2, France 2	210 pounds.
Rutile	100	Australia 92, Sierra Leone 8	242,200 tons.
Selenium	29	Canada 28, other 1	454,000 pounds.
Silver	27	Canada 16, Peru 5, Mexico 2, Honduras 2, other 2	34,686,000 ounces.
Tantalum	100	Canada 46, Congo (Kinshasa) 21, Brazil 17, Spain 5, Burundi-Rwanda 3, United Kingdom 2, Argentina, Australia, Belgium-Luxembourg, Cameroon, Cyprus, Japan, Nigeria, Portugal, Spain, Western Africa, 6.	523 tons.
Tellurium	20	Peru 11, Canada 9	64,000 pounds.
Tin	100	Malaysia 63, Thailand 30, Indonesia 3, other 4	46,100 long tons.
Tungsten	0		(18,171,000) pounds.[1]
Vanadium	22	Republic of South Africa 13, Chile 5, U.S.S.R. 3, other 1	1,033 tons.
Zinc	59	Canada 32, Mexico 10, Peru 6, Australia 3, Japan 2, other 6	795,900 tons.

[1] Net exports largely due to Government sales.

Note: Figures in parens are net exports.

STATEMENT OF GEORGE FUMICH, JR., DIRECTOR OF COAL RESEARCH, DEPARTMENT OF THE INTERIOR

The program and goals of the Office of Coal Research are to develop methods and processes for converting our abundant domestic coal supplies to clean forms of gaseous, liquid, and solid fuels; to develop cleaner and more efficient methods of generating electricity from coal; to find better methods of burning coal in its conventional form without damage to the environment; to develop improved methods of mining and processing coal to remove those contaminants which may pollute the atmosphere or create corrosion and slagging problems when coal is burned; to find constructive uses for the waste products of coal processing and utilization; and to develop this technology without the creation of new ecological problems and at minimal cost to the ultimate energy consumer—the American citizen.

Historically, U.S. energy consumption has grown at a rate slightly slower than Gross National Product (GNP). Because of improvements in the efficiency of energy use, there was a slow decline for more than 50 years in the amount of energy required per unit of output in our economy. More recently, the use of energy has increased faster than GNP. Since 1966, the amount of energy consumed per unit of real output has been rising. The historical energy growth rate of about 3½ percent suddenly increased to an annual rate of about 5 percent from 1965 to 1970.

More and more energy will be required to sustain our economic growth and the quality of our life. Some environmentalists believe that a slowdown in energy consumption and economic growth could be a solution to ecological problems. However, most economists agree that our economy must expand in real GNP if we are to have full employment and improved living standards. Further, the Nation is committed to a steady growth of the economy. We want to approach full employment and assure jobs for our growing force; we want to rehabilitate our cities and provide a better living standard for our poor; we want mass transit systems; we want to clean up our air, water, and land; and we want a whole host of other things to upgrade the quality of our lives.

Currently, oil supplies about 43 percent of our total energy consumption; natural gas, 33 percent; coal, 20 percent; hydropower, 3.8 percent; and nuclear, 0.3 percent.

Known reserves of oil and gas are insufficient to maintain these ratios in the years ahead. Severe gas shortages from conventional domestic sources can occur within this decade. In contrast, our coal reserves are adequate to meet anticipated requirements for hundreds of years.

The estimated total remaining coal resources of the United States as of January 1, 1967, have been estimated by the U.S. Geological Survey as being 3,210 billion tons of which 50 percent, or 1,605 billion tons is considered minable by known technology.

Significant progress has been made by the Office of Coal Research in the technology of converting coal to pipeline gas. OCR has in operation several coal conversion gasification pilot plants and supporting projects. Research to date has been evaluated by OCR and by outside consultants and has been deemed promising. There is sincere and eager interest on the part of gas companies, and participating financial support by the American Gas Association (AGA).

In June, the President sent an energy message to the Congress that included an accelerated coal gasification program. On August 3, Secretary Morton signed an agreement with AGA which provides for expenditure of $30 million per year for four years. AGA will provide one-third of this funding. The program will hasten the day when coal to gas plants will be a commercial reality.

Synthetic petroleum products from coal, particularly low-sulfur fuel oils, could help to solve some of today's recognized energy and environmental problems. High-quality synthetic crude oil from coal could augment our Nation's reserves and insure potential independence from foreign sources. Construction and operation of plants needed to convert coal to such oil, gas, or power, could create numerous job opportunities in remote rural areas of the country. Creation of jobs in these areas would bring about an overall social benefit that would be beneficial to the entire country.

Equally significant, Eastern coal can be converted to oil and refined petroleum products which will reduce our dependence on imports in the late 70's and 80's. During a national emergency, synthetic fuel could be provided to the energy oriented Eastern U.S. from Eastern coal.

Another promising area is higher efficiency coal-based power systems that possess inherent benefits including coal resource conservation and reduction in thermal and atmospheric pollution. Some of these systems—now known to be technically but not yet commerically or practically feasible—have the potential of reducing thermal pollution by 33 percent per unit of electricity produced. These benefits result purely from increased efficiency. In addition the systems also show good potential for almost entirely eliminating air pollution from coal-fired generating systems.

In the area of power generation through the use of magneto-hydrodynamics (MHD), the Office of Coal Research has undertaken some work and is now formulating a major development plan in cooperation with the U.S. Bureau of Mines and the Electric Research Council. The general nature of this activity was recommended by an MHD Panel and submitted in June 1969 to the President's Office of Science and Technology. It has been estimated that years of high-level effort will be required to bring such a program to successful completion.

Improved power cycles can be developed based on gas turbines combined with coal gasification systems now under development as well as with simpler systems for providing clean fuel gas. Fuel cells have promise for ultimate efficiencies of 80% and should be developed for this reason. Additionally, fuel cell plants can be built in small sizes which will increase reliability of all power grids.

Today, we believe that we can foresee the ability to design coal-based systems that convert coal to clean gas—both high and low Btu; clean liquid—fuel oil, synthetic crude, refined petroleum products, chemicals; and to a clean solid—solvent refined coal, low in sulfur and ash. These products can be used in improved power cycles to produce electric power at low cost.

Coal is available across the length and breadth of the U.S. Synthetic fuels and low cost power from coal reduces dependence of the U.S. on foreign supplies and increases our national security in any emergency.

Answers to Questions of Chairman Patman

Following the hearing before the Joint Committee on Defense Production, on August 2, 1971, Chairman Patman submitted additional questions to the witnesses from the Department of the Interior who appeared before the committee. Answers to these questions were submitted for the record. The questions and answers are as follows:

Question. Secretary Dole, in referring to the development of mineral policies under the Mining and Minerals Policy Act, made reference to the many fragmented policies that are in effect today and administered by numerous agencies of the Government. Would you indicate some of the policies which must be carried out in the future to assure this country of adequate raw materials to meet the increasing demand?

Secretary Dole. Public Law 91–631, the "Mining and Minerals Policy Act of 1970," is the most recent statement of broad mineral policy by the Government. However, PL 91–631 does not provide any specific new implementing authority in that it directs the Secretary of the Interior to use "his authority under such programs as may be authorized by law other than this Act." Public Law 91–631 does direct the Secretary of the Interior to include in his annual report to the Congress a report on the state of the domestic mining, minerals, and mineral reclamation industries, together with such recommendations for legislative programs as may be necessary to implement the policy of the Act.

The Department of the Interior is currently engaged in a major coordinated effort reviewing the mineral position of the United States in the light of both present and future conditions in preparation for the Secretary's first report to the Congress under PL 91–631. Consequently, at this time, we are unable to comment as to any specific policies and programs that may develop from our review. At present the Government is guided not only by the broad policy of PL 91–631, but also by the policies contained in such other legislation as the "Defense Production Act of 1950," as amended, and the "Strategic and Critical Materials Stock Piling Act" of 1946, both of which are directed toward assuring adequate supplies of materials for national security purposes. Further, the many present authorities of the Department of the Interior are in large measure all directed toward increasing U.S. supplies of raw materials in areas under its policy and program jurisdictions.

I might make one further comment in this regard. It is, of course, essential that we continue to pursue our geologic mapping, our geophysical and geochemical surveys of selected areas within the two-thirds of the United States in which mapping is still inadequate to aid in the discovery of new resources and the appraisal of new and poorly known resources. It is also essential that we continue and accelerate research on new exploration techniques and methods.

Question. Would you outline the authority of the Department of the Interior as related to overcoming shortages in supply for metals and minerals?

Secretary Dole. The Department of the Interior has broad authority regarding supplies of metals and minerals which can be brought to bear on the problems of present or anticipated shortages. The Organic Act of the Bureau of Mines, as amended, cited in Dr. Osborn's statement, provides broad authority to conduct research and development on all minerals, mining methods, metallurgy, use of materials, conservation, and health and safety. The Organic Act of the Geological Survey, as amended, provides broad authority for geologic investigations including mapping.

The Secretary of the Interior has received broad delegations of authority under the Defense Production Act of 1950, as amended. Further, the Secretary of the Interior is specifically named in Section 303g of the Defense Production Act in connection with the development of substitutes for strategic and critical materials.

Under the Federal Coal Mine Health and Safety Act of 1969 and the Metal and Nonmetallic Mine Health and Safety Act of 1966, the Department of the Interior is working to improve safe working conditions in the mines of the Nation, which activity in the long run must surely aid in making for a more stable domestic mining industry, which in turn will thus help to overcome future shortages.

There are many other pieces of legislation under which the Department of the Interior has authority to assist in overcoming shortages in supply. For example, providing power (through its power administrations) for reduction of metals, leasing of public lands for exploration for minerals and for mining of metals and minerals, and specific assistance to exploration through the Office of Minerals Exploration Program.

The total authority of the Secretary of the Interior, derived from laws some of which date to the earliest days of the republic, is vast and exceedingly complicated, particularly as relates to the public lands of the United States. It is planned that the report of the Secretary under PL 91–631 will carry as definitive a listing of authorities as is possible.

Question. How accurate are the figures of the Department of the Interior covering reserves of metals and minerals located in foreign countries?

Dr. Paul Zinner. Quantitative reserve estimates are meaningless unless they are defined in terms of prices, or precisely stated technological assumptions, accessibility, time-frames or, particularly in regard to foreign locations, a variety of national policies. Moreover, the effect of changes in end-use patterns should be appraised to establish the meaning of accuracy. For example, fragmentary knowledge of a given resource potential may be accurate enough if foreseeable demand trends are sharply downward, but very precise information becomes necessary where demand trends are upward, established sources are limited, or any factor restraining access is present or imminent.

Figures for reserves of metals and minerals located in some foreign countries may be as accurate as those for reserves in the United States. Figures for reserves may be incomplete for countries that restrict the release of reserve data, such as the Soviet Union or the People's Republic of China. Figures for potential or uneconomic reserves (called "resources" in some tables) are not as accurate, but give the approximate order of magnitude of reserves. Figures for reserves from some foreign countries may be more revealing of the true volume of such reserves than comparable data from the United States because of the common domestic practice of withholding confidential company data from the records. The accuracy of data will vary with each commodity and with the general state of geologic knowledge and mineral exploration from one country to another.

Ready access to essential information varies widely from one commodity to another and between geographic areas. The instances where substantial improvements are necessary in the quality or availability of data, that are essential to effective planning, occur most frequently in four broad areas. These are:

(1) Current end-use patterns, and events that affect changes in such patterns.

(2) Cost-supply data, and the sensitivity of supply patterns to cost changes.

(3) Foreign consumption patterns.

(4) World reserve position and resource potential.

The reliability or level of confidence assigned to the basic information employed by the Bureau of Mines, with particular reference to World reserve position and resource potential, may be assessed initially in terms of the degree of out-and-out estimation required in the absence of any reliable data. For purposes of definition the general qualitative terms of good, fair, and poor are used to express the extent of estimation, and data are then regarded as:

"good"—if the amount estimated is less than 15 percent and the confidence level is greater than 85 percent.

"fair"—if the amount estimated is less than 35 percent and the confidence level is greater than 65 percent.

"poor"—if the amount estimated is more than 35 percent and the confidence level is less than 65 percent.

The following table summarizes, in these qualitative terms, the apparent reliability of the data presently available and used in the preparation of the information presented in the testimony before this Committee. Either a "good" or "fair" classification is considered an adequate data range for purposes of this assesssment.

APPARENT RELIABILITY OF DATA ON 81 MINERAL COMMODITIES

Data area	Data classified as— Good	Fair (number of commodities)	poor	Commodities having inadequate data (percent)
Domestic:				
Supply:				
Production	54	2	25	31
Stocks	34	6	41	51
Imports	54	0	27	33
Exports	37	4	40	49
Reserves	13	2	66	81
Demand:				
Consumption by end-use	28	3	50	62
Total consumtpion	45	3	33	41
Rest-of-the-world:				
Supply:				
Production	6	48	27	33
Reserves	4	10	67	83
Demand: Total consumption	2	29	50	62

Generally, one-third to one-half of the commodities lack adequate supply data. More than 80 percent have deficient reserve data. In more than half the instances, demand data are lacking or inadequate.

With specific reference to the accuracy of figures on reserves in foreign countries, the foregoing summary suggests that there are deficiencies in information in 67 of the 81 commodities for which reserve data are needed for minimal planning, evaluation and policy formulation processes. For comparison purposes it should be observed that the accuracy of figures relating to domestic reserves suffer similar inadequacies.

Question. Are there any employees of the Department of the Interior located in foreign countries who report on mineral resources?

Secretary Dole. No. Only Mineral Attaches, who are employees of the Department of State, are located in foreign countries for the sole purpose of mineral reporting. The Deparment of the Interior proposes candidates for Mineral Attaches and provides them with technical backstopping. At present there are only four Mineral Attaches although many more would be desirable.

Interior employees go abroad on assignments for the Agency for International Development and the United Nations. In the performance of their duties they may report on some aspect of the mineral industry of the country where they are located. But this is incidental to the performance of their duties.

Question. How accurate are the figures of the Department of the Interior covering reserves of metals and minerals located in the United States?

Mr. Radlinski. The reliability of U.S. ore reserve data varies widely for different minerals. In general, however, the reserve data are order of magnitude figures only. Accurate reserve data are known only to the mineral producers and then only for the mines under their control.

Inventories of metals and minerals located in the United States are classified in two categories—reserves and resources. Reserves are known materials that may or may not be completely explored, but that may be quantitatively estimated; they are considered to be economically exploitable at the time of the estimate. Resources are materials other than reserves that may ultimately be exploitable; they include undiscovered, but geologically predictable deposits of materials similar to present reserves as well as known deposits of materials whose exploitation awaits more favorable economic or technologic conditions. Data on reserves as defined above are generally available only for deposits in the process of being developed or extracted, or on nearby extensions of such deposits.

Figures for reserves in some locations are known to private companies but are withheld from the public record. Figures for domestic reserves of barite, bauxite, chromite, fluorspar, iron, light-weight aggregate, manganese, niobium-tantalum, rare earths, tin, tungsten, and vanadium—commodities given special attention by a limited number of Departmental experts—are probably more accurate and comprehensive than data available for other commodities.

Figures for resources as defined above are less accurate or reliable than those for reserves. They indicate essentially an approximate order of magnitude of mineral deposits. As with reserves, the accuracy of resource estimates varies with the commodity. Data for petroleum, or bedded deposits such as coal, iron ore, or phosphate are generally more accurate or reliable than data for sporadically distributed vein-type metalliferous deposits. Relatively accurate resource estimates are not available for many commodities, and much new work needs to be done to acquire such information.

Question. What metals and minerals are most likely to present shortage problems in the next 10 years?

Dr. Paul Zinner. Providing that: (1) our scientific capabilities and (2) our productive facilities for materials, including minerals, continue to develop over the next 10 years, it is difficult to point to any specific metal or mineral as most likely to present serious shortage problems in the next 10 years. Sudden and capicious politicio-economic interference with normal reliable foreign supplies is perhaps the greatest factor that is likely to cause problems. The table in Dr. Osborn's statement which projects primary mineral supply-demand relationships to the year 2000 indicates our best thinking of the magnitude of U.S. demand by that year and the size of possible shortfalls under varying assumptions as to supply. This table indicates the need for increasing our emphasis on mineral science and technology to prevent the major shortfalls that otherwise will most likely develop over the next many years.

Question. To what extent will improved technology lower the cost and increase the available supply of marginal and submarginal resources such as chromite and managanese ore?

Dr. Paul Zinner. Growth in technological capability has contributed to the solution of many problems relating to our mineral supply. However, the problem of technology is not alone one of science but one of economics as well. At a price, it is possible to produce minerals from marginal and submarginal resources. If this price is excessive, alternate sources or substitutes are sought.

The outlook is poor for improved technology lowering costs which would in turn increase the available supply of chromite from domestic marginal or submarginal resources. Current metallurgical technology in South Africa and Finland permits the use of low-grade chromite, but results in an inferior product according to American standards. As high quality chromite resources decline or through political situations these resources are denied to domestic consumers, marginal resources may be utilized, but at substantially higher costs. While improved technology would minimally improve the situation, transportation charges and rate of return on investment have an overriding influence on the economics of available supply.

Development of technology for recovery of chromium in some laterites could extend world resources and possibly spread the geographical supply base but at higher unit costs.

Improvements through technology with respect to manganese ore in the past can be said to parallel that of some years ago with respect to taconites. As long as good quality ores remain available from a variety of foreign sources at favorable prices, there will be little reason to consider the marginal and submarginal resources. When the situation changes and the need to consider them becomes pressing, those parties most interested will be able to adapt to their situation the technology that has been developed, improving it and lowering the costs as they work. Many years and much money have been spent in manganese research, and all the promising approaches have had considerable investigation. Barring the discovery of radically new technology, of which there is currently no indication, it would appear that there is little opportunity for further improvements in technology to lower costs or make marginal and submarginal manganese ores available except under the conditions stated above. A possible exception might be the current interest in sea-floor deposits of manganese modules. The well financed and unique approach to this area could result in something new. The present situation here is too conjectural to speak meaningfully at this time in terms of costs and tonnages in other than promotional terms.

Question. On the average are we processing lower grades of domestic ore from year to year?

Dr. OSBORN. Over time the average grades of ore mined must decline as the higher quality ores yield the greatest profit and will be mined first. Despite the long term downward trend, there are fluctuations including periods in which average grade is increased. During periods of low demand and low prices, there may be selective mining of higher grade ore to maintain a steady rate of income. Also, discovery of new rich deposits will temporarily raise the average grade. For example, the average grade of lead ore mined in 1950 was 2.6 percent, whereas in 1969 the grade was 4.6 percent. Discovery of a new rich lead belt in southeast Missouri led to this improvement.

More detailed data on the changes in grade of ore mined between 1950 and 1969 were transmitted to the Joint Committee on Defense Production on July 23. (See p. 274.)

Question. To what extent does the Export-Import Bank consult with the Department of the Interior when loans and guarantees are made for financing the production of metals and minerals in foreign countries? To what extent has the Agency for International Development, or the Overseas Private Investment corporation, consulted with the Department of the Interior when making loans and guaranteeing loans for the production of metals?

Secretary DOLE. These agencies have available to them all the regularly published information of the Bureau of Mines with respect to mineral production and anticipated future demand. For example: The "Minerals Year Book," "Mineral Facts and Problems," "Mineral Trade Notes," and "Mineral Industry Surveys" include historical data, current data, and future supply-demand projections. Published material from the Geological Survey is also available. In addition, staff members of the agencies consult with our staff specialists when amplifications of published data are required. However, there is no consultation with the Department of the Interior as to the suitability of loans and/or guarantees as affecting areas of United States interest for which the Department of the Interior has responsibility.

Question. What is the responsibility of the Bureau of Mines for maintaining statistics on resources and demand?

Dr. OSBORN. The responsibility for gathering statistics on minerals is contained in the various legislative acts pertaining to the Department of the Interior and the Bureau of Mines. Beginning with Public Law 386–62nd Congress, 3rd Session, "An Act to Amend An Act to Establish in the Department of the Interior a Bureau of Mines," approved February 25, 1913, the Bureau has been charged with conducting inquiries and investigations concerning mining, the utilization of mineral substances, and the economic conditions of the mineral industries, and publishing the results thereof. In 1925, with the transfer of the Bureau of Mines to the Department of Commerce, the Bureau absorbed the minerals statistics operations of the Geological Survey. The Bureau and its functions were returned to Interior in 1934. Subsequent appropriation acts for the Department of the Interior have provided funds for the Bureau of Mines to promote the conservation, exploration, development, production, and utilization of mineral resources including fuels.

To accomplish the charge placed upon the Bureau, mineral statistics are needed and are collected from producing and consuming firms on a voluntary basis. These statistics provide the basis for reliably assessing the situation in the domestic minerals industry relative to the recovery, processing, utilization, and the shifting demand for mineral commodities and to guide planning and research in the areas of conservation, exploration, and development of indigenous mineral resources.

Technical and economic data on foreign mineral resources, production, consumption, and international trade are also compiled and analyzed for use in fully assessing problems of mineral supply.

Resource investigations are made to gain better knowledge of the location, quantity, quality, and recoverability of specific mineral deposits and their possible future utilization.

Question. What information is maintained on the ownership and control of resources outside the United States, such as the long term contracts which have been signed by Japan?

Dr. Paul Zinner. No orderly compilations are kept of ownership or control of mineral resources either in the United States or in foreign countries. Some information of this type is available in company reports or is published in mining and commercial journals.

Individual commodity specialists maintain information files which include reports of changes in mineral ownership, participation of corporations in mineral ventures, and of principal mineral supply contracts. Based on this information, specific questions regarding ownership of certain mineral resources at a particular time usually can be answered.

Question. To what extent are we now dependent on foreign sources of supply for metals and ores?

Dr. Paul Zinner. The table headed "Comparison of Prevailing U.S. Primary Mineral Supply—Demand Ratios with Projected Historical Trends in Domestic Mineral Production—July 1, 1971," included in Dr. Osborn's statement, compares U.S. primary production to U.S. primary demand for the year 1969, and thus indicates our present dependency on foreign sources of supply. In most cases these ratios have not changed materially in the past ensuing year. The fifth column of that table, headed "Constant Ratio A/B," shows the *fraction* of total U.S. primary demand supplied by U.S. primary production. For example, the number 0.098 opposite "aluminum" shows that only 9.8 percent, or roughly one-tenth, of our primary aluminum came from domestic bauxite mines. Conversely, the remaining 90 percent came from foreign sources, some as imported bauxite, some as imported alumina, and some as imported aluminum metal. In contrast, the ratio 1.742 opposite "molybdenum" shows that U.S. primary production was 174 percent of domestic primary demand, much of the excess over 100 percent being exported, as molybdenum is a mineral product for which the U.S. is a major world supplier.

Question. Are we becoming more and more dependent on foreign sources of supply for metals and ores each year?

Dr. Paul Zinner. It is difficult to generalize as to variations in our degree of dependence upon foreign sources of supply for all metals and ores. For example, in the early days of World War II and of the U.S. Atomic Energy Program, the U.S. was almost entirely dependent upon foreign sources for uranium. Today, the U.S. has a current excess supply of uranium. The copper chart contained in Dr. Osborn's statement shows that domestic mine production of copper has gradually increased over the last 20-year period while demand too has gradually increased. As shown by the zinc chart, domestic mine production of zinc has held relatively uniform over the 20-year period, while demand has increased. Thus, domestic mine production of the zinc supplies proportionately less of total U.S. demand. In contrast, as shown by the chart on lead, domestic mine production of lead declined rather steadily from 1950 to about 1964. Since then, domestic mine production of lead has increased steadily as new mines, mainly in Missouri, have opened. Meanwhile demand for lead has not increased over the 20-year period to the degree that occurred in the case of zinc. Consequently, the proportionate share of the U.S. demand for lead supplied by domestic mines has recently increased.

The aluminum chart shows that domestic bauxite mines have produced bauxite at about a uniform rate over the last twenty years while demand for aluminous materials has greatly increased. Consequently, the proportionate contribution of U.S. bauxite mines to U.S. demand has declined steadily.

Of course, the United States is the number one producer of aluminum metal, using a combination of domestic ores, imported ores, and imported alumina (an intermediate between bauxite and aluminum). For some materials such as manganese, chrome, and primary tin, in the post World War II period, the U.S. has always relied almost wholly on imports. Our table comparing value of the United States primary mineral production and demand in 1969 with projected value in the year 2000 shows that there will be increasing dependence on foreign sources of supply for many metals and ores in coming years.

Question. Are our present policies adequate for meeting our needs for metals and ores?

Secretary DOLE. There is no doubt that our present national policies covering materials supplies and usage require serious review at the present time. Consequently, as previously mentioned, there were recently enacted into law both the Mining and Minerals Policy Act of 1970, (PL 96–631) and the National Materials Policy Act of 1970 (PL 91–512), both of which require reports to the Congress concerning supplies and uses of materials together with recommendations necessary for meeting the needs of the years ahead. Such inadequacies in present policies and programs as may be revealed by our studies should lead to recommendations for improvements.

Question. To what extent are we becoming more dependent on smelting capacity in foreign countries?

Dr. OSBORN. Trends in U.S. dependency on foreign smelting capacity for metals produced by smelting are indicated in the following tabulation. The tabulation shows the percentage of primary demand for metal met by domestic primary smelters from 1950 to 1970. For this tabulation smelting is broadly interpreted to include production of metal by distillation and the roasting-leaching-electrowinning process.

The tabulation demonstrates that the part of domestic demand for lead and zinc met by domestic smelters has decreased over the past two decades. Tin demand met by domestic smelters is down sharply over the same period.

With respect to copper, the 1950–55 dependency on foreign-smelted copper was probably higher than normal owing to the effect of the Korean emergency. A similar distortion in the 1966–70 period was caused by the 1967–68 copper industry strike. In the post-strike (1969–70) period, domestic smelters produced 98.5 percent of primary demand.

The trend with respect to aluminum likewise is distorted by the impact of the Korean War when foreign smelters supplied large quantities of aluminum. However, during the 1966–70 period, domestic smelters met a significantly smaller portion of the domestic demand for aluminum than they did in the 1956–60 and 1961–65 periods.

Metal	Percent of United States primary demand met by domestic smelters			
	1950–55	1956–60	1961–65	1966–70
Aluminum	79	92	83	78
Copper	76	92	92	83
Lead	78	81	62	64
Zinc	85	84	81	70
Tin	45	20	7	5
Antimony	69	91	82	66
Iron	98	99	99	99
Nickel	1	10	9	9

Question. When will satellites be used for exploration, and what results are expected from the use of satellites?

Mr. RADLINSKI. The first Earth Resources Technology Satellite (ERTS–A) will be orbited early in 1972. The satellite will aid mineral exploration by providing single orthographic photographs of areas up to 100 sq. mi.; by revealing major geologic structures where such structures are reflected by variations in soils and moisture content; and by revealing intrusive igneous bodies and zones of rock alteration related to mineral deposits. Features such as those often help to narrow the search for mineral deposits to the most favorable areas. Months or years of geologic mappings are generally required to find such favorable exploration zones. Satellite photographs can aid geologic mapping programs by narrowing down some potentially mineralized areas in which to concentrate mapping activities on the ground.

Question. Dr. Osborn, as Chairman of the Committee on Mineral Science and Technology, National Academy of Sciences, you made an interesting and disturbing report in 1969, which indicates there has been a decline in fundamental research and education in the mineral field in the United States. Can you tell us whether the National Science Foundation has been aware of the seriousness of this problem, and what priority the National Science Foundation places on mineral science and technology?

Dr. OSBORN. The National Science Foundation has long been aware of the national problems in the field of Mineral Science and Technology in the United States. The National Science Foundation has sponsored major improvements of scientific and technological education over the past many years. However, these improvements have been directed largely to science and engineering in general rather than to the specific disciplines of mineral science and technology. Perhaps, the closest to the field of Mineral Science and Technology are broad programs sponsored by the National Science Foundation over the years which have strengthened education and research in the geological and earth sciences. However, our 1969 study showed that for the year 1967 total federal support for the specific fields of Mineral Science and Technology was $12,685,000. The National Science Foundation's share was $2,878,000, of which $1,117,000 was directed to physical metallurgy, leaving only the following:

Mining	$82, 000
Extractive metallurgy	234, 000
Nonmetallic materials	761, 000
Petroleum engineering	5 ,000
Fuel science and technology	156, 000
Other mineral science and technology	523, 000
Total	1, 761, 000

The continued decline of education and research in the fields of Mineral Science and Technology makes it evident that more support is needed than has been available in recent years. It is hoped that the Bureau of Mines will receive sufficient financing in future years to permit direct support of the critical areas of Mineral Science and Technology.

Question. As dependence on foreign sources for materials increases, will there be need for stockpiling additional quantities of materials for defense purposes?

Secretary Dole. This would, of course, be a possibility but would depend upon the security needs of the country for particular minerals. The Director of the Office of Emergency Preparedness, under Presidential Executive Order 11051, determines what materials are strategic and critical and sets the quantities and quality of such materials which are to be stockpiled to meet national security needs.

Question. As the demand for materials increases, and our dependence on foreign sources increases, will industries be able to acquire materials to meet their needs for nondefense purposes without carrying additional inventories?

Secretary Dole. Regrettably carrying of large inventories often is discouraged by high interest rates and taxation based on value of materials. Many short-term national problems could be averted or ameliorated if industry were to carry sufficient inventories to cover temporary disruption of supplies through unexpected interference therewith by foreign politico-economic activities, work stoppages as in the case of nickel not too long ago, natural catastrophes, and the like. It would be highly desirable for industries in the United States to carry adequate inventories to cover temporary interruptions of supplies rather than to have them operate on a "hand-to-mouth basis." Just as a little money in the bank provides the individual with flexibility to meet unforeseen emergencies, so does a reserve supply of materials provide flexibility for industry. Also valuable is reserve productive capacity which would make possible production of additional supplies of materials on short notice.

Question. Secretary Dole states that we must work to retain and expand world markets for United States mineral production in order to maintain favorable trade balances. What minerals can be produced in quantity in the United States for export to other countries?

Dr. OSBORN. In 1969, exports of minerals and mineral products were valued at $4,675,044,000 subdivided as follows:

Metals (manufactured)	$1, 833, 720, 000
Mineral energy resources and related products	1, 130, 728, 000
Metals (crude and scrap)	711, 484, 000
Chemicals	538, 562, 000
Crude nonmetallic minerals	313, 420, 000
Manufactured nonmetallic minerals	147, 130, 000

For mineral exports to increase in such a way as to help maintain favorable trade balances at least two requisites are necessary. (1) The United States must have a supply of the given material larger than necessary to meet present and foreseeable near-term future needs, and (2) there must be foreign purchasers available with hard currency to purchase the material. There are a number of mineral materials which can meet the first test. However, the number of foreign industries with hard currency available for purchase of such United States minerals probably is a more limiting factor than the actual availability of certain materials.

Question. Mr. Radlinski states that the discontinued exploration program which was authorized in the Defense Production Act is credited with the discovery of mineral reserves valued at about $1 billion, and the Government's contribution totaled $23.3 million. What incentives would be required to encourage exploration and increase our known reserves?

Mr. Radlinski. The following types of programs offer incentive, directly or indirectly, for minerals exploration:

Financial assistance programs have offered aid on a participating basis with private industry to explore for certain minerals. These would include the Geological Survey's Office of Minerals Exploration (OME) program, 1958 to present, and its predecessor, the Defense Minerals Exploration Administration (DMEA) under DPA, 1951 to 1958. As mentioned earlier in my prepared statement, the OME program has not encouraged the private sector to participate in mineral exploration projects as expected, and the level of activity and the results achieved have been disappointing. Accordingly, a proposal recommending improvements in the program is under review. This type of program can be very successful as demonstrated by the DMEA program from the value of ore discovered and the value of returns to the Government through royalties on production, and, indirectly, through taxes.

Various tax incentives have been offered in the past and some are in effect at present. One incentive permits mineral producers to deduct expenses within established limits incurred in exploration and development from current gross receipts in computing taxable income. Increases in such allowable deductions would further encourage exploration.

A number of Government subsidy programs have been conducted under which the Government made payments to mineral producers when metal prices dropped below stated levels. These programs enabled some producers to continue operations during periods of low prices when properties otherwise would have been closed. However, these types of programs offer minor incentive to exploration.

Various Government purchase programs for mineral commodities, such as mica, beryl, manganese, and tungsten, have been conducted. Although some exploration resulted from these programs, their primary purpose was to encourage domestic production within a relatively short period of time.

Perhaps the most effective of these programs is the one offering tax incentives. This benefits all operators, large or small, and entails no Government expense.

The second most effective program is the one offering Government participation with private industry in exploration as demonstrated under the DMEA program.

Question. Mr. Ricca states that those who know the most about the occurrence of petroleum in the United States estimate that we have found less than half the amount of discoverable oil in the United States, and that another 436 billion barrels await discovery. Would you indicate what information is available on this estimate, and whether new technology will enable us to learn more concerning the quantity of oil which has not been discovered?

Mr. Ricca. The figure of 436 billion barrels of oil still to be discovered is the difference between the total amount of recoverable oil estimated to have been in place originally and the amount that has been actually discovered. Of the amount actually discovered, part has been produced and the balance is proved by drilling.

There is no known technology that will permit knowing the undiscovered reserves with greater precision. Such potential reserves, generally termed resources, are estimated by projecting the productivity of rocks in various geologic basins, based upon discovered fields, to the entire volume of rock in the basins. The principal aid to such projections is the degree of exploration to which the rocks have been subjected through exploratory drilling. Thus the only means of improving knowledge is through the process of drilling additional wells.

It would be useful, of course, to have an instrument which, operated at the surface, could directly detect crude oil in underlying strata. No such instrument has been developed to date, although much research has been devoted to the subject.

Question. Mr. Ricca states that most of the increased supply of foreign oil must come from the Eastern Hemisphere, and specifically the oil exporting nations of Africa and the Middle East which hold 80 percent of all free foreign reserves of crude oil. Would you indicate what our recent experience in dollar cost has been on price increases for oil from these countries?

Mr. RICCA. Relative to the recent negotiated agreements in North Africa and the Middle East, the tax paid costs of the oil industry's crude output have consequently gone up by about 40¢ per barrel for the 15 million barrels per day coming out of the Middle East, by 90¢ per barrel in Libya, 77¢ per barrel in Nigeria and 64¢ per barrel in Algeria. In the next five years alone the price increases built into the agreement will add further costs, notably over 20¢ per barrel in the Middle East.

Question. Although imported oil is said to be cheaper than domestic oil or oil from shale or coal, would our ability to produce oil from oil shale and coal improve our bargaining position in purchasing imported oil?

Dr. OSBORN. If and when oil from oil shale and coal were actually available in substantial volume, and truly price competitive on a delivered basis, our bargaining position should be improved. "Ability" (know-how) without demonstrated productive capacity, however, would not be an effective force. Unless the availability of these new energy sources is expedited through accelerated research and development, the time factor presents many imponderables, including logistics and costs of production, distribution, and utilization, plus environmental and other considerations.

Perhaps of equal importance with energy supply, whether competitive or otherwise, is the importance of these new sources of energy to our international stature, particularly with respect to national security and other strategic considerations through reduced dependence on foreign sources of supply.

Question. Do you have figures on the dollar value which is added to oil annually at refineries in this country?

Mr. RICCA. According to the Bureau of the Census data the value added to oil annually at refineries was as follows in millions of dollars:

1969	4,945
1968	4,839
1967	4,745
1966	4,099
1965	3,493
1960	2,773
1955	2,435

Question. Would you indicate some of the environmental problems which limit the increase in oil refinery capacity?

Mr. RICCA. There are several items to which objections have been raised from an environmental standpoint which have contributed to the limitation in expansion or construction of new refineries. Each of these items can be overcome to a large degree and in some cases completely but in every case additional and substantial investments are required. Most new refineries have been incorporating these investments. A real problem lies in the formidable task of convincing the public that these measures are effective in avoiding environmental interference.

Some of these items are:

1. *Noise.*—High capacity furnaces and catalytic cracking plants have generated noise at levels which have created problems in the past.

Solutions involve using waste heat boilers, muffling devices and revised furnace design. Noise is a problem only when the refinery is located close to populated centers or other industries which have a high density of personnel.

2. *Odor.*—Odor is caused by escape of hydrocarbon vapors, sulfurous compounds and sometimes stack gases.

Solutions involve installation of floating roof tanks or vapor recovery systems where hydrocarbons are stored.

Improved seals are available for pumps which potentially can lose hydrocarbons.

3. *Water Pollution.*—Many refineries use considerable amounts of water for cooling purposes and there exists the danger that oil may leak into the water and contaminate the streams into which the water is discharged.

Essentially all refineries have oil/water separators which are designed to prevent escape of oil with the effluent water. In some of the older refineries these separators have not always been as effective as might be desired. New techniques have incorporated involving settling ponds, filters, aeration systems and various treating techniques. With investment in proper equipment, water can be returned to streams or rivers in a condition to support marine life.

4. *Particulate Emission.*—Certain catalytic cracking plants emit a certain amount of catalyst fines which create a white plume which can be visible for some distance.

This problem is being largely overcome through installation of improved cyclone separators and waste heat boilers which remove the greater part of these particulates.

5. *Stack Gas Smoke and Odor.*—Refineries usually employ a number of fuel burning furnaces. However, as with all other industries they are required to comply with fuel sulfur content regulations. In this respect refinery stack gases should not pose any more of a threat to the environment than from many other industries and probably less of a threat than in the case of power plants.

6. *Fear of Fire and Explosions.*—It is true that refinery fires or explosions are a fearsome spectacle and do cause a great deal of damage on some occasions. With rare exceptions the damage has been confined within refinery limits. Also refineries have dramatically improved their safety record in terms of fatalities and injuries and compare favorably with other heavy industry.

Question. What amount of lead-time is required for the construction of oil refineries?

Mr. Ricca. The lead-time required for construction of refineries differs markedly according to the complexity of plant to be built. If a simple distillation plant is to be constructed, 15 months to 1½ years will suffice. If more complex downstream equipment such as cracking plants, reformers and cokers are involved (and this is often the case) the period will average 2½ years.

The times mentioned above are defined as the time elapsed from appropriation of funds by the board of directors of the company until the equipment is on stream making specification products. It should not be forgotten that engineers and technicians invariably must make feasibility studies taking several weeks to a few months to prepare before the project is presented for approval of the board of directors. In the above lead times no provision is made in time required for seeking a site or obtaining approval for construction.

Question. What would be the cost of building a commercial shale oil plant?

Dr. Osborn. Cost estimates developed for the Department of the Interior Proposed Prototype Oil-Shale Leasing Program cover several options and are based on the Bureau of Mines gas combustion process. For a minimum size commercial plant of 50,000 bbl/day capacity producing semirefined shale oil suitable for pipeline transport, and in terms of 1970 dollars, the capital costs using underground mining with mine disposal of spent shale are $187.2 million for equipment and $35.2 million for labor. Under the option of open pit mining with backfill, the same size plant would again require $35.2 million for construction labor but only $178.5 million for equipment. These estimates include general environmental safeguards and may vary at least 10 percent.

Other estimates made in developing the cited program include $323.7 million for a 100-thousand bbl/day plant with the underground option, $426.0 million for a 150-thousand bbl/day plant using open pit; and for a non-nuclear in situ retorting plant of 50,000 bbl/day, $213.9 million in equipment and $19.8 million for labor was calculated using the same assumptions.

Question. Is there now a tight tanker market for transporting oil?

Mr. Ricca. There is *not* a tight tanker market during the summer of 1971. This is indicated by the level of spot tanker rates (single voyage charters) which have dropped to approximately Worldscale 60 during July. With greater consumption of petroleum during winter months on world markets, it is expected that spot rates will increase to possible Worldscale 80 or 90 during the winter. However, even these rates do not reflect a tight tanker market. The last tight tanker market occurred during the second half of 1970 and the first two months of 1971 when spot tanker rates approached the level of Worldscale 300.

Question. What percentage of oil imports are transported in American tankers?

Mr. Ricca. Most imports of oil to the U.S. are believed to be carried in American owned tankers; however, the actual percentage is not known. Imports of crude oil are probably predominantly carried in American owned vessels while it is likely that some residual fuel oil imports are carried in foreign owned tankers.

Very little imports of oil are carried in U.S. Flag tankers since few U.S. Flag tankers operate in foreign trade, except for military or grain cargos.

Question. Since recent tanker rates for transporting oil are reported to be high, is there any indication of lower tanker rates in the future?

Mr. RICCA. Tanker rates were high during the second half of 1970 and the first few months of 1971. New charter rates have declined, thus charter rates for single voyages (spot rates) are at low levels this summer. New longer term charters for one year or more are now being made at lower levels. However, most of the longer term charters made last fall and last winter at high rates will continue until the charter runs out. Thus, the average tanker rate will gradually decline over the next few years if there are no interruptions to international oil movements. In view of large increases in the cost of building tankers, long term tanker rates are not likely to decline to previous levels.

Question. Are there relatively few ports in this country which can accommodate large oil tankers?

Mr. RICCA. There are no existing ports in the U.S. which can handle tankers larger than 80–100,000 deadweight tons. Most tankers being constructed at the present time are over 200,000 deadweight tons, and there are a few tankers now operating over 300,000 deadweight tons.

Question. Since the sale of energy in the United States has grown faster than the gross national product for the past 5 years, do you forecast a continuation of this growth trend?

Mr. RICCA. The ratio of U.S. energy consumption to real GNP had been on a long term downward trend since the end of World War II until 1966 when it took a sharp upward direction. Reasons underlying these trends are numerous as well as complex; there is no simple basic relationship between GNP and energy.

Underlying the current upward trend are such factors as the growth in industrial output, the increased demand for air conditioning and the general trend toward electricity (a less efficient form of energy utilization). With a continuation of these factors and with increasing emphasis on air quality control, it is difficult to foresee energy growth trends reverting to their earlier relationships and to GNP.

Question. What shifts do you foresee in the uses of oil, coal, and uranium in the next 10 years?

Mr. RICCA. Between 1970 and 1985 the nuclear generation of electric power as forecast by some studies is expected to increase tenfold; by the latter year, it may provide nearly 16% of U.S. energy needs versus 0.3% last year. Use of coal will increase from 527 to 850 million tons, if technological advances permit its use within air quality standards, but its position may nonetheless decline from 20.3% to less than 17%. Oil will remain the "swing" fuel, with its consumption rate being heavily dependent on available supplies of other fuels. A recent forecast by the Bureau of Mines projects oil consumption of 23.6 million barrels a day in 1985. This represents 35.6% projected national energy requirements, down from 43.0% in 1970. Other projections, including one by the Department's Office of Oil and Gas, foresee higher oil requirements principally because of anticipation of lower gas supplies.

Question. What are some of the decisions which must be made in order to provide adequate quantities of energy for the next ten years?

Mr. RICCA. To provide adequate quantities of energy for the next ten years decisions must be made concerning:

1. What constitutes an acceptable level of dependence on foreign energy sources.
2. National policies which will induce the development of domestic energy supplies sufficient to limit foreign dependence to that acceptable level.
3. A balancing of national energy and environmental objectives.

Some specific issues which must be resolved include:

1. Offshore oil and gas leasing and development policies and procedures.
2. Acceptable development and distribution procedures for Arctic oil and gas.
3. Optimum use of Naval Petroleum Reserves.
4. Recasting of the Oil Import Program to suit the changing views of the next decade and to promote a stable investment planning base.
5. Development of technologies to permit the clean combustion of domestic coal.
6. Siting problems for power plants, refinery distribution systems and deepwater terminals.

7. Objectives and practices in the regulation of natural gas prices.

Question. Since some of the potential sources of energy—including the gasification of coal, the breeder reactor, and shale oil—may not be developed for many years, will the United States be able to produce adequate quantities of energy to meet demand in advance of developing these new sources of supply?

Mr. RICCA. The trend toward increased U.S. dependence on foreign energy supplies is already well under way. It will take a conscious act of national will and policy to reverse the trend but it could be done, even in advance of the breeder reactor and technologies for the production of synthetic fuels.

There is strong geologic evidence that the Nation has sufficient resources of conventional oil and gas to bridge the gap between the present and the advent of new technologies. The missing ingredient is a demonstrated willingness to accept the cost of developing these indigenous resources as a matter of national policy.

The following table shows some estimates of major energy resources and cumulative demand for the U.S. through the year 2000 (all figures in quadrililon Btu).

Resource	Estimated recoverable reserves	Estimated cumulative demand	Demand as a percent of recoverable resource
Bituminous coal and lignite	19,557	1,058	5
Petroleum	2,975	1,730	58
Shale oil	464	116	25
Natural gas (dry)	2,477	1,166	47
Uranium	325	804	248
Thorium	2,901	138	5

The estimated recoverable resources are based on current economics and technology, and the estimated cumulative demand is based on the maximum foreseeable use of energy.

To summarize, the U.S. cannot have energy self-sufficiency without a significant shift in energy consumption patterns, particularly to coal or coal derivatives, and/or significant incentives to the fuels industries, including increased prices for nuclear fuels.

Question. What are the estimates on the time required to develop new sources of energy such as shale oil, the breeder reactor, and the gasification of coal?

Dr. OSBORN. Shale oil development is now in the pilot stage. Demonstration-scale plants are expected to be in operation by the late 1970's. Progress in developing commercial shale oil production facilities is expected to be slow at first with a significant impact on domestic oil supply from this source not expected before the mid-1980's.

Breeder reactor technology is also presently in the pilot plant stage. The only U.S. fast breeder reactor for power generation, the Fermi Plant in Michigan, has suffered severe technological and economic setbacks. The AEC breeder program anticipates successful demonstration scale prototype operation by the mid-1980's. If so, significant impact on power generation by breeder reactors may be felt by 1990, and by 2000, or soon thereafter, this could become the dominant source of electrical power. A more informed opinion on the trends in breeder reactor technology should be solicited from the AEC.

An accelerated development program, including several pilot plants and at least one demonstration plant, should lead to the commercial availability of pipeline gas from coal in the latter seventies. There have already been some announcements by industry that some commercial synthetic producing plants based on naptha or on coal gasification will be in production prior to 1980, and it is predicted that by 1980 significant gas will be produced from such sources.

Question. If the estimates on the time required to develop new sources of energy such as shale oil, the breeder reactor, and the gasification of coal should prove to be incorrect, what will be the alternative sources for energy?

Dr. OSBORN. Any time lag in the development of new domestic energy sources will have a significant impact on our energy supplies, especially over the long term and in proportion to the time lag involved. As has been pointed out, the U.S. appears to have adequate overall fossil fuel resources through the year 2000. This assumes, however, that economic incentives will be adequate for domestic development of our resources and a shift to more intensive use of coal and that we are willing to accept appreciably higher prices for nuclear fuels. If these assumptions are unwarranted, our major alternatives will be increasing dependence on foreign petroleum and liquefied natural gas for our energy needs with the inherent risks to national security that are involved, or the relaxation of environmental restrictions compatible with factually demonstrated minimal levels of need.

Any ambiguity in the above is a result of unpredictable slippages in research and development for new energy sources. The greater the slippage in development of new energy sources the more the dependence on either coal for the production of electricity or the increased reliance on foreign sources of supply.

Similarly, as breeder reactors are assumed feasible by 1990, the greater the slippage in R & D, the greater will be our reliance on higher priced uranium, with its attendant higher electrical costs, or the greater the shift to the use of coal for power generation.

Question. Would you indicate the required steps to be taken in developing these new sources of energy?

Dr. OSBORN. Significant progress has already been achieved in pilot plant testing of oil shale and coal gasification technology. More research at this scale of operations is needed to evaluate the economics of alternative techniques of in-situ extraction, retorting and gasification. Some Government assistance will be required to expedite progress through the pilot plant and prototype stages of technology, but this continuing progress seems well within grasp in the light of developments to date.

The situation is quite different regarding the breeder reactor where considerable difficulty has been encountered in demonstrating the feasibility of the basic technology. Continued governmental support of experimentation at this stage and, eventually, for the development of prototypes is required to bring commercial breeder reactor power plants into being.

Apart from developing or improving the basic technology of shale oil extraction and coal gasification, certain other steps need to be taken to put these processes on a commercial footing. Since most of this country's oil shale resources lie in Federal land, the Federal leasing policy will be of great importance. Secretary Morton's June 29, 1971, announcement of the "Prototype Program" of oil-shale development represents a major step in determining the future course of oil-shale leasing. A program of consolidating Federal oil shale lands into large, economically minable blocks would also enhance the prospectives for a viable oil-shale industry. Other factors that might inhibit an efficient leasing program, such as the many mining claims for other minerals associated with oil shale, should be resolved. Permitting the taking of the depletion allowance on oil from shale or pipeline gas from coal at an advanced stage of processing would add economic incentive and perhaps hasten the establishment of commercial operations.

A considerable volume of water for fuel processing as well as for a resident worker population will be needed when a large scale shale-oil industry, or a coal gasification industry based on western coals comes into being. Steps should be taken well in advance of such developments to secure whatever water supply is yet available in that area to meet the impending need.

Question. Would you compare the potential environmental problems for the breeder reactor, the gasification of coal, and the production of shale oil?

Mr. FUMICH. The largest quantity of solid waste will be produced from shale oil refining. Coal gasification will require the disposal of ash, but the tonnage will be much less. The breeder reactor will produce a small quantity of highly radioactive waste. In the first two instances, as the processing plants will be at the mine mouth, it will be possible to dispose of the solid waste in the mined out areas as part of the land reclamation process that will be required. Radioactive wastes must be placed under impregnable safeguards in perpetuity, which may cause problems. All three systems will be designed to produce negligible air pollution. All three will require the disposal of waste heat, but the use of dry air cooling in at least the first two will minimize environmental effects. Coal gasification and oil shale processing to a somewhat lesser extent will consume substantial quantities of water as a hydrogen source. When the fuel is burned, the hydrogen is converted to water so that, in effect, it is recycled.

Question. The future demand growth rate for natural gas is estimated to be at the rate of 1.9 percent to 3.4 percent annually in the United States. Is this growth rate limited because of an estimated shortage of supply?

Mr. RICCA. It has been projected that the United States could use at least 33 trillion cubic feet of gas by 1980 if we can get it. But the National Petroleum Council projects 1980's available supplies at less than 22 trillion, assuming a continuation of present policies and practices. This latter figure represents essentially no increase over the present rate of gas consumption.

Question. Mr. Ricca states that the reserve-to-production ratio is currently about 12 to 1, compared with 20 to 1 in 1960. Do you have figures on the amount of money being expended annually in searching for natural gas as compared with earlier years?

Mr. RICCA. Chase Manhattan Bank reports that in 1969 capitalized and expensed outlays for production of oil and gas (including natural gas plants) in the United States totaled $5,475 million. Expensed exploration outlays comprised $725 million of this total. In terms of current dollars, the total 1969 outlay was exceeded only in 1968 and the expensed portion is the highest on record. Figures for selected years are shown below:

	Actual production outlays (capitalized and expensed)	Exploration expenses included in the previous column
1969	$5,475,000,000	$725,000,000
1968	5,640,000,000	715,000,000
1964	4,610,000,000	650,000,000
1959	4,500,000,000	650,000,000

Because oil and gas are commonly explored for and produced jointly, and because exploration and development activities overlap in the case of successful exploratory wells, separate data cannot be developed for gas exploration.

Question. The average annual demand for natural gas during the next 10 years is estimated to be about 27.5 trillion cubic feet a year and the United States has been adding only 15.2 trillion cubic feet annually to reserves, oil imports are expected to double in the next 10 years, and nuclear power development is reported to be behind schedule. Should the United States establish energy goals in an effort to eliminate or improve these supply-demand imbalances and to focus attention on the seriousness of potential energy shortages?

Mr. RICCA. The components of President Nixon's June 4 Energy Message must be considered in this context. Actions proposed are designed to meet both present and future energy needs. The creation of a single structure within the Department of Natural Resources where energy policy will be completely integrated and energy resource development programs combined will improve our capabilities to meet energy requirements.

In his energy message the President indicated the need to avoid waste, and for informed consumer decisions in energy usage. Conservation at every phase of the energy cycle is essential, not only to save energy, but to prevent avoidable environment deterioration. We can make the market work for us in efficient energy use if we provide the mechanism to insure that the consumer pays the full social and economic cost of his energy. Conservation at the market place operates when the goods offered for the consumer's choice are correctly valued. Government for its part must strike a compromise set of policies that will accommodate the goals of national security, low cost, and environmental safeguards, which in themselves are not compatible.

Question. Mr. Ricca states that we face increasing dependence on imports of natural gas as well as oil. What are the cost estimates for liquefied natural gas imports as compared to natural gas now being transported by pipeline?

Mr. RICCA. Average interstate wellhead price of natural gas is 18.3¢ per MCF with an average city gate price in the range of 45c per MCF. Delivered costs of LNG imports are reportedly in the range of 65 to 80c per MCF. This phase of the industry is in its very early development so cost figures may be subject to substantial change.

Question. What are the advantages and disadvantages of storing liquefied natural gas in large quantities?

Mr. RICCA. Natural gas production and transportation costs are lowest when facilities are utilized at near-capacity rates. Consumption of natural gas, on the other hand, is highly seasonal, especially in the Northern residential and commercial markets. To the extent feasible, seasonally variable demands are balanced with more stable supply rates through storage of gas near points of consumption.

Large volumes of gas are stored most economically in gaseous form in depleted gas fields or other natural underground storage areas. However, such areas are seldom found as close to consuming areas as would be desirable.

Natural gas in a liquid form occupies but 1/600 the volume of the same amount of gas in gaseous form. Significantly smaller tankage requirements are achieved at the cost of reducing gas to its liquid form and maintaining it in this form in specialized tankage. Liquefied gas storage has obvious advantages when the gas is received in liquid form as it would be in LNG imports.

Question. To what extent can industry shift from one fuel to another when there are shortages in supply?

Dr. OSBORN. As distinguished from a permanent shift from one source of energy to another, your question is considered to mean the extent to which there is flexibility for the temporary use of alternative sources of energy, following which the consumer may or may not return to his original energy source.

The ability to shift from one energy source to another on a short term basis is extremely limited, because of differences in fuel burning plants and equipment. On the one hand, it is relatively easy to shift from coal or oil or natural gas, principally through the installation of pipes in furnaces or under boilers. Because of the greater availability of coal, however, the preferability in emergencies generally is to shift the opposite way—from oil or gas to coal. This is very difficult, however, because coal in bulk form cannot readily be burned in furnaces designed for liquid or gaseous fuels; nor do plants for the latter have flues, smoke stacks, or storage and waste disposal facilities readily amenable to a shift to coal, except at very great expense.

The principal extent to which shifting among energy sources is feasible is at electric utility plants which have multiple fuel burning facilities—for burning either, or a combination of, coal, oil, or natural gas. This does not mean, however, that individual plants burn all types of fuel for which they have facilities.

For the most part such plants tend to use one type of fuel exclusively or predominantly. In New England, for example, in 1969 approximately 80 percent of installed generating capacity in Connecticut had multiple fuel burning equipment, with 77 percent capable of burning either coal or oil. Contrary to a few years ago, however, when coal was the predominant fuel, these plants were mostly 100 percent on oil. For the State as a whole, consumption was 68 percent oil and 32 percent coal. Similarly in Massachusetts, where 71 percent of generating capacity had multiple fuel burning equipment, half of such plants burned oil exclusively. Fuel consumption for all plants in the State was 79 percent oil, 19 percent coal, and 2 percent natural gas.

In New Jersey and New York, where 86 percent and 71 percent of generating capacity had multiple fuel burning facilities, consumption for coal, oil, and gas was 32, 57, and 11 percent, respectively, in New Jersey, and 47, 37, and 16 percent in New York.

Coal, of course, predominated in coal-producing and nearby States, except in Iowa, where natural gas edged coal. In other areas, multiple facilities were either for coal and gas or oil and gas.

Question. What would be the best means of providing for an energy reserve for use when there are shortages of energy?

Secretary DOLE. The best means of providing energy reserves for use during shortages of energy supply is the practice followed by many consumers of maintaining stocks, or other assured supplies, at reasonable levels above requirements—with increases in stock levels when threats to supply are foreseeable or when prices are considered favorable. This practice most nearly follows normal procedures of obtaining supplies and thus minimizes the inconviences and added costs which generally occur when supplies become tight.

The application of this principle differs for the respective energy sources, of course, because of physical differences in the nature (the differentiation between bulk, liquid, and gaseous fuels). Also, cost factors can be a limitation, for energy stocks and storage or transportation facilities represent substantial investments. On the other hand, costs of added security of supplies must be measured against the need for continuity of operations, particularly where public concerns are a consideration.

Among alternatives is the maintenance of supplementary supplies by energy producers, such as stockpiles at coal mines (generally an abnormal practice except for unit trains); and the use of tanks or other facilities, such as offshore vessels, by suppliers of oil and natural gas. These in turn, however, represent additional investments or other costs which generally are reflected in higher prices to consumers.

For coal, one of the best assurances for continuity of supply is the ready availability of railroad coal cars to the mines. When such cars are in short supply, coal production is limited accordingly.

Another, but limited, alternative is the establishment and maintenance of multiple fuel burning plants, particularly by electric utilities, which permits the utilization of more than one type of fuel. Not only does this permit a given plant or system greater flexibility of operations during emergencies, but it enables them to exchange, or share with others, the power produced, through the use of interconnections or grids.

Relaxation of environmental restrictions during energy shortages would permit the use and increased availability for storage of fuels not otherwise permissible because of quality differences, but which are in greater supply, usually at lower costs, than the higher quality products.

Question. Are there relatively few companies who are engaged in the gathering of natural gas, as contrasted with companies transporting and distributing natural gas?

Mr. Ricca. Natural gas may be gathered by gas producers or by specialized gathering companies which sometimes are subsidiaries of pipeline companies. The term "gathering" may be used loosely to refer to the transport of gas from the wellhead to a natural gas plant or transmission line, or from the gas plant to the transmission line. If a transmission line acquires gas directly from a gas plant, no plant-to-line gathering may be involved.

The Federal Power Commission currently regulates 123 companies engaged in interstate gas activities; it classifies 24 of these as gatherers. Obviously many more companies engage in gas gathering, either to supply interstate gas markets, or prior to the point where the FPC assumes jurisdiction. This point has been a matter of some controversy, and a more detailed discussion of it might better be supplied by the FPC.

The gas distribution function is commonly performed by local utility companies whose numbers are considerably greater than their pipeline suppliers.

Question. Why is natural gas demand growing faster than natural gas reserves in the United States?

Mr. Ricca. The regulated price for natural gas has been the factor that made natural gas less attractive as an investment and conversely its low price made it more attractive as a fuel entering markets that it probably would not have entered if its value had been set by the market.

For years the nation has used the gas reserves discovered during the search for oil but not used because of the lack of long distance transportation facilities. We are now required to find new gas and the money requirements for this search must compete with all other options open to investors. Most companies find it more attractive economically to put money in other areas where the return on investment is greater.

Question. Does the high cost of maintaining inventories of natural gas relate to the shortage of natural gas?

Mr. Ricca. There is no relationship between the overall supply of natural gas and the cost of maintaining inventories. Most natural gas remains in the ground until it is needed in the market place.

Above ground storage or specially prepared underground storage is expensive and the industry has developed patterns to avoid storage as much as possible. One of these methods, interruptible sales, is a means of using excess gas during times of low consumption by residential and commercial users.

As we enter a new era in the marketing of natural gas, storage costs for such items as liquefied gas and gas produced at reforming plants, will add noticeably to the overall cost.

Question. What are the possibilities of obtaining natural gas from Canada?

Mr. Ricca. The U.S. now imports about 4% of its natural gas from Canada and there are good possibilities of increasing this. However, reserve-production ratios in Canada have started to decline in recent years and, thus, large increases in imports of natural gas from Canada will depend on the results of future exploration activity in Canada, especially the possibility of finding large reserves of gas in the Canadian Arctic or in the offshore areas of Eastern Canada.

In 1970, Canadian gas imports were about 800 billion cubic feet and the Canadian National Energy Board has forecast that, at most, Canada will be able to supply us with not more than 2.3 trillion cubic feet of gas in 1980.

Question. Does the experience of the Bureau of Mines in operating a pilot plant for recycling metals enable you to forecast the results to be achieved from operating a larger recycling plant?

Dr. OSBORN. The Bureau is presently operating a pilot plant to recover the minerals and metals from municipal incinerator residues. The pilot plant has a capacity of ½ ton per hour. Information based on operation of the small plant indicates that the process is technically sound and shows favorable economics. However, it is essential that a large demonstration-size plant be constructed and operated for a sufficient period of time to convince private and public officials of its practicality and potential.

Very rarely is any innovative technical process brought to commercial use without an intermediate scale-up test program. A demonstration-size plant would be the means of obtaining firm data on operating costs, product quality, profit margin and process operating characteristics. In addition, it would make available tonnage quantities of glass, iron products, and nonferrous metals for evaluation and market studies.

Question. Are some countries dependent on secondary materials for a high percentage of total requirements of materials?

Dr. OSBORN. All of the major industrial countries have highly organized secondary metals industries and have developed a significant dependency on scrap metal supply. Data are not available to compare the relative dependency in different countries for all commodities, but the following examples are illustrative of the range: United Kingdom derives 50 percent of its aluminum supply from scrap, compared with 33 percent for Italy, 31 percent for Germany, and 25 percent for the United States. For lead, however, the United Kingdom derives only 25 percent from secondary metal compared with 42 percent in the United States. In the case of copper, United Kingdom, Germany, and France obtain about 25–32 percent of supply from scrap whereas the United States obtains nearly 50 percent and Italy 40 percent.

The principal industrial countries use about one-third scrap and two-thirds ore to make iron and steel. Smaller countries using only electric furnaces to make steel are much more dependent on scrap—sometimes 100 percent.

Question. To what extent do industries in this country stockpile scrap and secondary materials?

Dr. OSBORN. Metal producing companies hold only small stocks of prepared scrap, say 1 to 3 months supply. There is always, however, a large reservoir of scrap in old automobile hulks and other forms that are scattered about the country. During the periods of high demand and prices, this type of scrap is collected and used.

Question. What is the cost of recovering metals from most grades of scrap as compared to the cost of new metals?

Dr. OSBORN. The costs of producing primary and secondary metals are not truly comparable. Under normal circumstances, however, market forces will tend to equalize the average total costs including price of the raw materials.

There is, of course, a range in the profitability of mines and of operating reclaiming plants. New metal can be produced more cheaply from a rich or favorably situated mine, than from a low grade, or deep or remote deposit. Similarly, clean scrap generated near reclamation plants costs less overall to recover than contaminated material scattered about in several locations and not easily accessible to transportation facilities.

Question. What is the responsibility of the Department of the Interior in connection with the recycling of materials?

Dr. OSBORN. The Department of the Interior's Bureau of Mines has been concerned with the recovery and recycling of metals and minerals from waste sources for over 50 years. One of the missions of the Bureau is to conduct inquiries and research on the wise and efficient use of our resources from any source, to ensure that the Nation has an adequate supply of mineral raw materials. The Bureau's original authority and responsibility for recovery and recycling of minerals and metals is inherent in the Organic Act of 1910 (as amended in 1913 and 1915), that established the Bureau of Mines. Therefore, the Solid Waste Act of 1965, as amended by the Resource Recovery Act of 1970 is not to be interpreted as the single authority under which the Department's Bureau of Mines derives its authority or responsibilities in this area. The responsibilities of the Department of the Interior in reclamation, disposal, and recycling of a variety of metal, mineral, and energy laden solid wastes was explicitly restated and strengthened by the recently passed Mining and Minerals Policy Act of 1970 (PL 91–631).

Question. How can the Federal Government promote recycling through its own purchasing practices?

Dr. Osborn. The Federal Government can purchase supplies that are (1) made in whole or in part from recycled materials, (2) designed for each recycling, and (3) packed in containers which are easy to recycle.

Standards have already been set for the amount of recycled fibers to be contained in paper products purchased by the Federal Government. In addition, re-refined lubricating oils could be purchased for automobiles, trucks, planes, etc. Recapped tires could be used on Government vehicles. Bricks used for the construction of Government buildings in states such as Utah, Arizona, and Nevada could be made from mine wastes. Refuse resulting from the mining of anthracite coal could be required for roadbed and for making non-skid highway surfaces when highway construction is financed by the Federal Government. If the road surfaces were concrete, fly ash could be the required aggregate.

The least complex materials are usually easiest to recycle. Therefore, metal alloys used in equipment and containers purchased by the Government should contain the smallest number of elements required to yield the desired properties and should be made of the fewest number of alloys. For example, all aluminum and all steel (no tinplating) cans are easier to recycle than tin cans or steel cans with aluminum tops. Purchase of printing inks which are easy to remove would aid in the recycling of paper.

Purchase of supplies packed in materials made from recycled fibers and/or recycled plastics would also encourage recycling.

Question. Will subsidies be required in order to encourage the recycling of materials?

Dr. Osborn. Subsidies may well be required to develop and demonstrate new technology required to increase the rate of recycling. However, subsidization of commercial recycling processes might be required only in certain situations.

Subsidies may be required to encourage the use of additional steel scrap for all or some of the following reasons. Much steel and other scrap materials are widely scattered across the country. Junked automobiles, tin cans, and glass bottles are good examples. Cost of collection and transportation to a reclamation plant would be high. Once collected, some scrap must be treated to remove impurities and costs may make this scrap more expensive than scrap not requiring treatment. When steel scrap is ready for shipment to the mill it faces a freight rate which is higher per iron unit than the freight rate on ore. In addition, the cost of prereduced iron pellets is steadily decreasing to the point where it may not be possible to collect and ship scrap at a profit and still be competitive with pellets.

Paper also faces a transportation problem. The paper mills are located near pulp wood sources and far from urban centers which are the sources of waste paper. Therefore, recycled fiber faces two transportation charges in contrast to the single transportation charge for fiber obtained from pulp. A subsidy to cover the transportation of waste paper back to the mill would encourage paper recycling.

While not directly in the realm of a discussion of subsidy, tax policy should also be noted. Currently, lubricating oils made from petroleum are not taxed to the same extent as re-refined oils. The result is that most used lubricating oils are poured into sewers or burned instead of being recycled. This constitutes a waste of a natural resource and causes air or water pollution problems.

Finally, it should be emphasized that some recycling processes are more profitable than the wasteful practices they replace and will therefore not require subsidies. Each case must be examined on an individual basis.

Question. Does unused scrap tend to deteriorate because of corrosion?

Dr. Osborn. Unused scrap metal deteriorates if exposed to a corrosive environment, However, all types of environments are not corrosive to all metals, and the same environment will corrode different metals to varying degrees.

Aluminum, copper, brass, bronze, and zinc either do not corrode in dry air or corrode at very low rates. However, soft water (such as rain or dew) will dezinc some brasses and dissolve metallic zinc. The presence of moisture and sulfur dioxide enhances the corrosion of brass, bronze, and zinc. Moisture plus chlorine, and salt or caustic solutions will attack aluminum. Copper will corrode only under the most severe circumstances.

Iron is by far the most common metal most subject to deterioration by corrosion. Iron corrodes in moist air forming a scale which does not adhere well to the metal. Thus, some surface is always available for continued corrosion. If the scrap steel or iron is jarred the scale can be knocked loose or abraded leaving additional bare metal surface.

66-335—71——6

Question. Is there a limit to the amount of scrap which may be used by industry?

Dr. OSBORN. In certain industries there is a limit to the amount of scrap materials which can *presently* be recycled using certain processes. However, it is hoped that research will increase these limits and will result in the discovery of new recycling processes and the development of new markets for scrap.

Scrap steel is limited to about 30 percent of the metal processed in the Basic Oxygen Furnace (BOF), the remainder being molten pig iron. Use of excess scrap would result in the molten steel being too cold. It is hoped that research will produce an economical preheating technique which would allow increasing the present limit to 40 percent. In contrast the electric furnace can be operated using 100 percent scrap. However, electric furnace steelmaking is slower. Also, the use of scrap in the electric furnace is being contested by the increased production of iron pellets.

There is no limit to the amounts of aluminum, copper, zinc, lead, and mercury which can be recycled. The problems with these metals involve collection and/or separation from alloys.

Of the most important non-metals, glass can consist of up to ⅓ recycled material, and waste paper can certainly be increased from the present low of 20 percent to at least 40 percent. At present there are no commercial processes for recycling plastics. However, the Bureau of Mines is actively working towards solving the problems involved in plastic recovery and reuse.

Question. Are there problems in reclaiming metals due to the metals being contained in alloys?

Dr. OSBORN. One of the most important problems is recovering valuable elements such as chromium, cobalt, nickel, vanadium, and molybdenum from high-temperature alloys. Because of the expense involved in processing this type of alloy scrap in the United States much of it is exported abroad rather than recycled here.

Problems exist in recovering aluminum and zinc from die casting alloys. Some aluminum based alloys also pose difficulties. Research is in progress in Bureau of Mines laboratories to develop methods for recovering pure aluminum and silicon from certain of these alloys. In the case of other alloys research is aimed at obtaining pure cathode aluminum while concentrating any copper, zinc, and precious metals in an anode slime which can be further treated. In the case of titanium alloys the problem elements are aluminum and tin.

Question. What progress has been made on the gasfication of coal? What programs are in effect to encourage the development of the gasification of coal, and what amount of money is being expended annually by the Government and by private industry?

Mr. FUMICH. The Office of Coal Research has one coal gasification pilot plant completed and in the preliminary operation stage, a second near completion, and a third being designed. The Bureau of Mines has one being designed. Projections for these processes, based on extensive laboratory and bench scale experimentation, indicate that they will be capable of producing synthetic natural gas at competitive prices. In accordance with the President's energy message of June 4, 1971, the Department of the Interior has reached an agreement with the American Gas Association (AGA). This calls for an accelerated and expanded gasification development program over the next 4 or 5 years to cost $30 million a year, one-third of which will be funded by AGA. Implementation awaits the appropriation by Congress of an additional $10 million for Fiscal Year 1972.

A number of gas transmission and distribution companies are making engineering studies of coal gasification, although their expenditures are not known. AGA has expended at least $300,000 a year for many years increasing to perhaps $1 million in the last year. Government expenditures approached $10 million in Fiscal Year 1971. The Fiscal Year 1972 Office of Coal Research appropriation is $9,720,000 with a supplemental request for $10,200,000 now before Congress.

Question. When gas is produced from coal, do you simplify the problem of separating the sulfur from the coal?

Mr. FUMICH. In converting coal to gas, the raw gas must be scrubbed before the final catalytic methanation stage. This scrubbing removes the sulfur which can be converted to elemental form. The process is simple and convenient, compared with flue gas cleaning, for instance.

Question. What is the maximum sulfur content of coal which may be used in powerplants?

Dr. OSBORN. From a technical viewpoint, coal of highest sulfur content marketable can be used in powerplants. New environmental regulations, however, are the basis of restrictions on the use of coal from sulfur standpoint.

Question. What is the best method of utilizing coal which contains a high percentage of sulfur?

Dr. OSBORN. For generation of power in plants that have installations which remove SO_2 from the stack gasses: or for conversion of coal to low sulfur gas or liquid energy fuels.

Question. Does coal mined in the eastern part of the United States, where a higher percentage of coal is consumed, contain more sulfur?

Dr. OSBORN. Decidedly yes. Based on a 1970 preliminary total of 602 million tons for United States coal production, approximately 60 percent (about 360 million tons) was classed as medium to high sulfur content coals. Also it should be noted that about 95 percent of all coals produced in 1970 came from coal areas east of the Mississippi River.

Approximately 59 percent of the 1970 coal production was shipped to electric uitlities. These coals averaged about 2.3 percent sulfur on a weight basis.

With respect to the sulfur content of estimated remaining reserves of all coals in the United States, about 65 percent or about 1,023,634 million tons is estimated to be 1.0 percent or less. The bulk of these coals is located west of the Mississippi River and in general is of lower rank (less heat values per unit weight) than eastern U.S. bituminous coals.

Question. What is the estimated cost of a commercial plant for the conversion of coal into gas?

Mr. FUMICH. A recent estimate for HYGAS commercial plant using an electrothermal gasifier and generating its own power internally, with a capacity of 250 million cubic feet per day indicated an investment of $170 million. The mine was not included. If electrical energy were purchased, the required investment is $108 million. All the above are 1970 cost estimates.

Question. Are adequate plant location sites available for converting coal into gas?

Mr. FUMICH. Based on a confidential study. AGA has publicly announced that 176 suitable sites (20 east of the Mississippi) have been located. Each site must have 20 to 30 years' coal reserves—150 to 200 million tons—and an ample water supply. It will require about this number of 250 million cubic-feet-per-day plants to meet an estimated 15 trillion cubic-feet-per-year shortage by 1985.

Question. Will different processes be required to convert different types of coal into gas?

Mr. FUMICH. Coal is a highly variable substance and it is quite likely that different processes will be optimum for different coals. One of the objectives of the gasification development program described previously is to determine this.

Question. Would you indicate the amount of electric power to be used in converting coal into gas in a commercial plant?

Mr. FUMICH. The electrothermal HYGAS process mentioned a moment ago is the most intensive electricity consumer—350,000 k.w. Other processes will be in the range of 10,000 to 15,000 k.w.

Question. What amount of coal did we export last year?

Dr. OSBORN. In 1970 coal exports totalled 71,767,182 short tons and comprised 70,908,218 tons of bituminous coal, 789,499 tons of anthracite, and 69,465 tons of coal briquets. In addition, 2,513,678 tons of coke was exported during 1970 making a grand total of 74,280,869 tons of coal and coke exports for the year, the second highest of record.

Not included in reported U.S. export data are shipments for use by military installations abroad. In 1970 such shipments amounted to 931,876 tons consisting of 692,060 tons of anthracite and 239,816 tons of bituminous coal.

The distribution of bituminous coal exports in 1970 by major regional world markets and estimates of the quantities used in metallurgy is shown below, in thousand short tons:

Destination	Total exports	Used in metallurgy	Percent metallurgical
Canada	18,673	6,900	37.0
South America	2,920	2,891	99.0
Europe:			
E.E.C	16,566	11,103	67.0
Other	4,938	4,884	98.9
Japan	27,601	27,601	100.0
Other	201	173	82.4
Total or average	70,908	53,552	75.5

Question. Are there projections for larger exports of coal in future years?

Dr. Osborn. Yes. In general the projections by various groups approximate 105–110 million tons by 1980, with continuing growth to the year 2000, as compared to 56 million tons in 1969 and 71 million tons in 1970. The latter were considered abnormally high, however, so that exports for 1971 are expected to be slightly above the midpoint between 1969 and 1970. Nearly all projections relate to increasing demand throughout the world for coking coals for steelmaking.

Since the world's known deposits of coking coals are limited, and U.S. reserves of these premium quality coals are considered to be more than adequate for internal metallurgical requirements, the demand for American coking coals is expected to remain strong in the future.

Question. What are the projections for expenditures on coal research in future years? Would you indicate the projected steps to be taken in coal research in future years?

Mr. Fumich. As mentioned, there is a plan to expend about $30 million a year (one-third industry funded) for coal gasification research for the next 4 or 5 years. After that, the construction and operation of a demonstration plant will require increased funding, perhaps $50 million per year for 3 years, presumably with a larger share from industry.

About $10 million a year is now budgeted for the development of processes for making synthetic petroleum and other clean fuels, such as low-ash coal, from coal. While the petroleum problem is not now as pressing as gas, it appears that we will become increasingly dependent on foreign oil. For this reason, it will be desirable to continue at least the same level of funding in this area for the next 10 years.

A small MHD development program has been started. ($1 million for FY–1972). Discussions with industry concerning a cooperative program are underway. To bring this program to a successful conclusion—the attainment of clean commercial size coal fired MHD electric generation systems approaching 60 percent thermal efficiency—will require at least 10 year's time and the expenditure of $200 to $300 million.

Question. Is progress being made in reducing pollution from coal?

Mr. Fumich. The programs for producing clean fuels from coal previously described will do much to reduce pollution from coal. The achievement of 60 percent thermal efficiency in the generation of electricity from coal will in itself greatly reduce thermal and air pollution. Likewise, it will greatly reduce the cost per unit of electricity generated of controlling polluting emissions.

Question. What amount of coal is being mined per man-hour in comparison with earlier years?

Dr. Osborn. I am proud to submit a table, which details salient coal production facts for the ten year period (1960–69) and shows a steady increase from 1.60 to 2.49 tons per man-hour over that period. The 55.6 percent increase in productivity was experienced during a corresponding increase in annual coal production of 145 million tons and a decrease of nearly 45,000 men in the daily working force. The two principal factors that contributed to the increased productivity were (1) the closing of many small mines of relatively low efficiency and (2) the opening of large, highly mechanized modern mines, which also were primarily responsible for the increase in production.

Although it is anticipated that over the long term productivity will continue to increase, during the transition period in which the mines adjust to requirements of the new Health and Safety regulations (which require new types of permissible equipment and the assignment of some of the working force to nonproductive tasks), it is possible that productivity will decline, or at least maintain the reduced rate of growth that was characteristic of the late 1960's.

SALIENT FACTS ABOUT U.S. COAL PRODUCTION—1960–69

Year	Production (thousand short tons)	Number of men working daily	Average days worked	Net tons per man per day	Net tons per man-hour
1960	415, 512	169, 400	191	12.83	1.60
1961	402, 977	150, 474	193	13.87	1.73
1962	422, 149	143, 822	199	14,72	1.84
1963	458, 928	141, 646	205	15.83	1.98
1964	486, 998	128, 698	225	16,84	2.10
1965	512, 088	133, 732	219	17.52	2.19
1966	533, 881	131, 752	219	18.52	2.32
1967	552, 626	131, 532	219	19.17	2.40
1968	545, 245	127, 894	220	19.37	2.42
1969	560, 505	124, 532	203	19.90	2.49

Question. What other possibilities are there for developing new uses for coal through research?

Mr. FUMICH. By far the greatest consumer of coal will continue to be the energy market—gas, liquid fuel and electricity. Some work is being done on the production of acetylene—a chemical building block—from coal. It seems quite certain that as large gas and liquid fuel plants come into being a synthetic organic chemical industry based on coal will be a byproduct. Some research along these lines will be called for of course, but it does not seem pressing at the moment. Much of it has already been done: the original synthetic organic chemical industry was based on coal before the birth of petrochemicals.

Question. Please set forth the extent to which uranium, coal, oil, and natural gas are owned and controlled by the same companies, including a list of the companies and the percentage of ownership in each of these energy resources?

Dr. OSBORN. Known interrelationships are given on the attached tables. Much of this information is qualitative, as obtaining firm quantitative data would require an extensive search of Bureau of Land Management lease records and Securities and Exchange Commission annual reports. The interrelationships among oil and gas producers cannot be unraveled in the time available.

Approximately 25% of 1969 bituminous coal production was controlled by oil firms. Large coal reserves are leased or owned by oil firms which have not brought these properties into production. A few oil companies are important producers of nuclear materials, and many more are entering the field through exploration and joint ventures.

This report contains 1969 figures for coal production, reserves when available, percentage of total coal production, and public land leases held. Uranium figures for 1969 are not available in such detail as much information is AEC confidential, and is not available in annual reports or other public sources. Nominal mill capacity, mill ownership, annual industry capacity, and oil company areas of activity are given. While only a few oil companies are actually producing uranium, many are prospecting. Often, prospecting is being done as a joint venture, or on private land, and the oil firm's interest is not easily discovered.

ENERGY INDUSTRY OWNERSHIP

(1) Energy interests of the twenty-five largest petroleum companies ranked by assets, as of early 1970 (2 pages)

(2) Coal owned by petroleum firms—1969

(3) Descriptive notes on petroleum industry coal interests (2 pages)

(4) United States uranium ore processing mills (operating or under construction)

(5) Present and planned uranium production by industry type

(6) Notes on uranium (4 pages)

I Present or future areas of oil company capability, either directly or through subsidiaries, in the nuclear industry

II Energy producers with nuclear interests, and known joint ventures, partnerships, etc.

III Descriptive notes on oil industry uranium holdings and available cross relationships

(7) Electric utilities owning coal companies

(8) Other industries owning coal companies

ENERGY INTERESTS OF THE 25 LARGEST PETROLEUM COMPANIES RANKED BY ASSETS, AS OF EARLY 1970

Petroleum company	1969 assets [1] (thousands)	Energy source interests				
		Gas	Oil shale	Coal	Uranium	Tar sands
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Standard Oil (N.J.)	$17,537,951	X	X	X	X	X
Texaco	9,281,573	X	X	X	X	
Gulf	8,104,824	X	X	X	X	X
Mobil	7,162,994	X	X		X	
Standard Oil of California	6,145,875	X	X			
Standard Oil (Indiana)	5,150,677	X	X		X	X
Shell	4,356,222	X	X	X	X	X
Atlantic Richfield	4,235,425	X	X	X	X	X
Phillips Petroleum	3,102,280	X	X		X	
Continental Oil	2,896,616	X	X	X	X	
Sun Oil	2,528,211	X	X	X	X	X
Union Oil of California	2,476,414	X	X		X	
Occidental [2]	2,213,506	X		X		
Cities Service	2,065,600	X	X		X	X
Getty [3]	1,859,024	X	X		X	
Standard Oil (Ohio) [4]	1,553,591	X	X	X	X	
Pennzoil United, Inc	1,356,832	X			X	
Signal	[5] 1,258,611	X				
Marathon	[6] 1,221,288	X	X			
Amerada-Hess	982,157	X			X	
Ashland	846,412	X	X	X	X	
Kerr-McGee	667,940	X		X	X	
Superior Oil	494,025	X	X			
Coastal States Gas Producing	[5] 490,190	X				
Murphy Oil	343,914	X				

[1] "Moody's Industrial Manual," June 1969 and 1969 annual reports.
[2] Includes Hooker Chemical Co.
[3] Includes Skelly and Tidewater.
[4] Includes reported British Petroleum.
[5] As of June 30, 1969.
[6] As of Sept. 30, 1969.

Source: Table adapted from Bruce C. Netschert, et. al., "Competition in the Energy Markets," National Economic Research Associates, Inc., Washington, D.C., 1970.

COAL OWNED BY PETROLEUM FIRMS—1969

Petroleum company	Production (thousand tons)	Sales (thousands)	Reserves (billion tons)	Percent of total coal production	Public land coal leases	Acres leased	Public estimated reserves (million tons)	Total acreage
Continental	60,904.0	$244,700	7.0	12.0	16	37,892	715	NA
Occidental	30,348.8	192,513	4.1	7.0				
Sohio	11,997.4	55,165		2.0				
Gulf	7,615.6			2.0	5	1,815	8+	
Shamrock Oil	408.8			.07				
Belco Petroleum	1,742.0			.31	1	4,551	48	
McCulloch Oil Corp	1,248.6			.22				
Falcon Seaboard, Inc	2,639.2			.47				
Zapata Norness	1,030.3			.19				
Western Transmission Co	790.2			.14				
U.S. Natural Resources, Inc	126.3			.02				
Atlantic Richfield					17	37,423	643	215,000
Humble-Carter					3	15,491	164	
Concho Petroleum					10	8,595	106	
Kerr-McGee					6	15,427	253	123,000
Seneca Oil					1	6,336	93	
Sun					1	14,680	155	
Total				24.40				

Source: Data compiled from Moody's, Annual Reports, BLM sources, and Keystone Coal publications.

Descriptive Notes on Petroleum Industry Coal Interests

PETROLEUM COMPANY AND COAL OWNERSHIP CHARACTERISTICS

Standard Oil (N.J.)—Humble subsidiary has extensive holdings in midwest coal fields which were turned over to a subsidiary Carter Oil Co. In 1969 Monterey Coal Co. was organized, and first mine in Carlinville, Illinois is scheduled to reach an annual production of *3 million tons* in 1971.

Texaco—West Germany holdings?

Gulf—Bought Pittsburgh-Midway September 1963.

Mobil—Recent high bidder on 4000 acres of federal land in Wyoming.

Shell—Unconventional Raw Materials Group—exploration permits on 83,000 acres of coal on Crow Indian Reservation in Montana.

Atlantic Richfield—Extensive acreage—215,000 net acres—Joint venture with Hydrocarbon Research, Inc.—coal liquefaction.

Continental—Owns Consolidation (largest coal company) coal reserves total 7 billion tons.

Sun—Extensive holdings; no firm figures available.

Occidental—Bought Island Creek—third largest coal company. Bought Maust Coal & Coke Corp in August 1969 which added 30% to Island Creek's sales volume.

Standard (Ohio)—Owns Old Ben Coal Corporation—aggressive program to acquire coal reserves to be developed when justified by demand.

Ashland—A division of Ashland Resources has 50% interest in Arch Mineral Corporation. Arch has acquired coal reserves and developed mines which will be producing 3.35 million tons/year in less than 2 years.

Kerr-McGee—Substantial coal reserves—Choctaw mine in Okla., expected to produce 1 million tons/year of metallurgical grade in 1971. Low sulfur deposit delineated in S. Illinois, seam 5–8′ thick, 700–900′ deep. Total coal leases of 123,000 acres.

Diamond Shamrock—Acquired Pickands Mather Coal Company—primarily supplies steel industry with raw materials.

Belco Petroleum—Acquired Hawley Fuel Corporation in 1968.

Zapana Norness—March 1970—acquired Boone County Coal Corp. December 1969—agreed to acquire Barnes and Tucker Coal Co.

Consolidated Oil & Gas—Acquired lands in western Pa. and W. Va. for conversion into synthetic pipeline gas to supplement natural gas supplies.

California Time Petrol., Inc.—20 year mining lease on Burlington Northern's Roslyn—Cle Elum coal field near Seattle.

El Paso Natural Gas—Leased coal reserves in southern part of New Mexico.

Columbia Gas System—Columbia Coal Gasification Corp—To identify reserves and sites in Appalachian area.

Western Transmission Co.—Oil interests 0—Owns Canterbury Coal Co.

U.S. Natural Resources—Oil interests—acquired Twilight Ind., Inc.

Concho Petroleum—20% owned by J. C. Karcher (Dallas, Texas) has reserves. (Not registered, little data available.)

McCulloch Oil Corp.—Kingdom Come and Maxietta Coal Companies produced approximately 0.25% of total U.S. production in 1969.

Two firms with both oil and coal holdings are:

Falcon Seaboard, Inc.—Breathitt County Coal Corp.

Mapco, Inc.—Webster County Coal Corp.

The above notes were gathered from a wide variety of sources, including annual reports, national coal assoc. releases, trade journals, etc.

TABLE 4.—U.S. URANIUM ORE PROCESSING MILLS (OPERATING OR UNDER CONSTRUCTION)

Firm, and known ownership	Location	Nominal capacity (tons ore per day)
Operating:		
Anaconda Co	Grants, N. Mex	3,000
Atlas Corp	Moab, Utah	1,500
Center Corp	Canon City, Colo	450
Dawn Mining Co. (parent: Newmont Mining)	Ford, Wash	500
Federal-American Partners	Gas Hills, Wyo	950
United Nuclear—Homestake Partners	Grants, N. Mex	3,500
Kerr-McGee Corp	do	7,000
Petrotomics Co. (50 percent Kerr McGee) (50 percent Shelly Oil, Getty Oil).	Shirley Basin, Wyo	1,500
Susquehanna-Western, Inc	Falls City, Tex	1,000
Mines Development Inc. (subsidiary)	Edgemont, S. Dak	650
Union Carbide Corp	Rifle, Colo	} 1,500
Do	Uravan, Colo	
Do	Natrona County, Wyo	1,000
Utah Construction & Mining Co	Gas Hills, Wyo	1,200
Western Nuclear, Inc. (owned 100 percent by Phelps Dodge)	Jeffrey City, Wyo	1,200
Under construction or planned:		
Continental Oil (joint venture with Pioneer Gas)	Texas	(1)
Humble Oil	Wyoming	2,000
Rio Algom	Moab, Utah	(1)
Susquehanna-Western, Inc	Ray Point, Tex	1,000
Utah Construction & Mining Co	Shirley Basin, Wyo	1,200
Total known		29,150

[1] Unavailable.

Source: Adapted from AEC "Statistical Data of the Uranium Industry," Jan. 1, 1970.

TABLE 5.—PRESENT AND PLANNED URANIUM PRODUCTION BY INDUSTRY TYPE

Energy industry type	Production (tons) 1969	Production (tons) 1973	Reserves $8 per lb. U_3O_8	Forward sales (tons through 1984)
Oil as primary revenue source	4,370	6,030	214,000	38,000
Percent of total	(31)	(34)		
Oil as subordinate revenue source	2,540	2,504	NA	NA
Percent of total	(18)	(14)		
Coal or gas as primary revenue source	2,800	3,030	NA	NA
Percent of total	(20)	(17)		
Totals, including producers not included above	14,000	18,000	492,000	85,000
Percent of total for above categories	(69)	(65)	(43.5)	(44.7)

Source: AEC contacts.

Notes on Uranium

I Present or future areas of oil company capability, either directly or through subsidiaries, in the nuclear industry.

II Energy producers with nuclear interests, and known joint ventures, partnerships, etc.

III Descriptive notes on oil industry uranium holdings and available cross relationships.

PRESENT OR FUTURE AREAS OF OIL COMPANY CAPABILITY, EITHER DIRECTLY OR THROUGH SUBSIDIARIES, IN THE NUCLEAR INDUSTRY

Company	Exploration or reserve holdings	Uranium mining and milling	UF_6 conversion	Fuel preparation or fabrication	Fuel reprocessing	Reactors
Standard Oil (New Jersey)	X	X		X		
Gulf	X			X	X	X
Arco	X		X	X	X	
Continental	X	X				
Getty	X	X		X	X	
Standard Oil (Ohio)	X	X				
Kerr-McGee	X	X	X	X	X	
Sun	X	X				

Source: Netschert, "Competition in the Energy Markets."

ENERGY PRODUCERS WITH NUCLEAR INTERESTS, AND KNOWN JOINT VENTURES, PARTNERSHIPS, ETC.

(JV—JOINT VENTURE)

A. Oil Companies

Atlantic Richfield.
Cities Service—JV U.S. Steel.
Continental Oil—JV Pioneer Natural Gas.
Gott—Skelly, Petrotomics (50%). JV Cleveland-Cliffs.
Gulf—Bokum Corp., Canadian uranium property.
Ibexco—Intern, Nuclear.
Kerr-McGee—Petrotomics (50%). JV King Resources.
Mobil.
Marathon—JV Earth Resources.
Pennzoil—Duval. JV Teton.
Phillips.
Standard Oil (Ohio)—Reserve Oil & Gas.
Standard Oil (N.J.)—Humble.
Standard Oil (Ind.)—Amoco.
Sun—Cordero. JV Nedco.
Tenneco.
Union of California—Minerals Explor. Co.
Group Total

B. Oil as Subordinate Source of Revenue

Atlas Corp.—Atlas Minerals, Shiprock Ltd. (40%).
Denison Mines—JV SOMIREX, JV Japanese interests (has large Canadian Mill).
Earth Resources—Vitro Minerals, JV Marathon.
King Resources—Colorado Corp., JV Kerr-McGee.
Newmont Mining—Dawn (51%). Newmont Explor., Ltd.
New Park.
Santa Fe Ind.—Santa Fe RR.
Union Pacific—JV German interests.
Union Carbide—Foote lands controlled.
Group Total

C. Natural Gas or Coal Production Involved

Am. Metal Climax—*Coal* production in east (Uranium mill down and dismantled).
Consol. Oil & Gas—(*Gas*) Nuclear Reserves, Petro Nuclear.
Colo. Interstate—(*Gas*) Colo. Oil & Gas.
Federal Interstate—*Pratt Coal Co.*
Houston Natural *Gas*—Houston Oil & Minerals, JV Ranchers Exploration.
Pioneer Natural *Gas*—Pioneer Nuclear, JV Continental Oil.
Homestake—Enerdyne. *Coal* lands leased.

Utah Const. & Mng.—Major *coal* operations.
Continental Oil—*Consolidated Coal Co.*
Denison—Major *coal* position planned.
Gulf—*Pittsburg-Midway Coal Co.*
Union Pacific—Major *coal* land control & production.
Kerr-McGee—*Coal* production in Oklahoma.

Descriptive Notes on Industry Uranium Holdings and Available Cross Relationships

Kerr-McGee—Owns ½ of national capacity to convert U_3O_8 to UF_6 (fuel used by reactors). Has 23% of uranium milling capacity with additional 4% gained thru ½ ownership of other properties. Prospective uranium lands maintained at approximately 1,600,000 acres by a continuing process of testing, selection and acquisition. Has total contracts of 51,147,000 pounds of uranium oxide. 1969 cap. expenditures for nuclear activities $39,298,889. 1969 sales of U_3O_8 concentrate—4,305,493 lbs.

Pennzoil United, Inc.—Uranium prospect in Powder River Basin of Wyoming—Exploration and evaluation.

Sohio—Has interests in 250,000 acres of potential uranium lands in Wyoming, Colorado, and New Mexico; and a 50% interests in a 120,000 acre ranch in Laguna uranium mining district of New Mexico. Maintains an intensive exploration program.

Occidental—Occidental Minerals Corporation (Oxymin) is evaluating uranium prospects in the U.S. and Canada.

Atlantic Richfield—Searching for uranium in U.S. and Canada. Has a nuclear materials and equipment subsidiary. ARCO is one of 2 companies able to convert slightly enriched uranium to UF_6, and only company with capacity for converting highly enriched uranium to UF_6.

Gulf—Gulf Mineral Resource Company—wholly owned subsidiary—Has a uranimum discovery at Saskatchewan. Gulf General Atomic Incorporated is capable of designing, building and fueling nuclear reactors.

Continental—During 1969 completed over 1.9 million feet of exploration and definition drilling. Holds 490,000 net acres of prospective uranium lands. Plans to build a $12 million mine and mill complex w/initial capacity of 1.5 million pounds of uranium concentrate by late 1972. Has entered sales agreement which requires deliveries totaling 1.8 million pounds of uranium concentrate over a five year period starting in 1973.

Electric Utilities Owning Coal Companies

Alabama:
- Alabama Power Co.
- Southern Electric Generating Co.

Montana and North Dakota: Montana-Dakota Utilities Co.

Ohio:
- Ohio Edison Co.
- Ohio Power Co. (American Electric Power System).

Pennsylvania:
- Duquesne Light Co.
- Pennsylvania Power Co. (Ohio Edison Co.).
- West Penn Power Co.

Washington: Pacific Power & Light Co.

West Virginia:
- Appalachian Power Co. (American Electric Power System).
- Beech Bottom Power Co. (West Penn and Ohio Power Companies).
- Central Operating Company (Owned jointly by Appalachian Power Company and Ohio Power Co. of American Electric Power System).
- Monongahela Power Co. (West Penn Power Co. and American Electric Power System).
- Ohio Power Company (American Electric Power System).

Wyoming:
- Black Hills Power & Light Co.
- Pacific Power and Light Co.

APPENDIX

Statement of Senator John Tower

Mr. Chairman: I appreciate the opportunity to present my views to this committee concerning our nation's increasing reliance on foreign sources for supplies of mineral resources, many of which are of strategic importance.

I am particularly concerned about two mineral resources which are key elements of our national security. These two are crude oil and natural gas.

In a Senate statement of July 14, 1971, I detailed my position concerning our increasing reliance upon Middle East sources of supply to meet increased demand for crude oil. In that statement I noted that unless present trends are altered, we could be forced to rely on Middle East sources for up to 62 percent of our crude oil requirements by 1985. By 1973, we will probably have used up our excess crude oil producing capacity. With your permission, Mr. Chairman, I would like to insert my statement in the record of these hearings.

I am also deeply concerned about the availability of our producing reserves of natural gas. At the present time, natural gas supplies one-third of our energy needs. Thus, maintaining abundant producing supplies of this energy resource would be in our national security interest.

Yet, because of shortages of natural gas, potential users are being denied the use of this ideal, clean-burning fuel.

Mr. Chairman, with your permission, I would like to insert in the record at this point my August 5th statement dealing with the current natural gas situation.

These serious supply problems are especially unfortunate when one considers that we possess enough undiscovered supplies of these two resources to meet our needs for several decades. It has been reliably estimated that there exist undiscovered recoverable reserves of over 430 billion barrels of crude oil and over 1,000 trillion cubic feet of natural gas in the United States.

Declines in domestic exploration activity for new reserves of oil and gas account for this present dangerous supply situation. I am confident that the deliberations of this Committee will reveal the seriousness of our supply situation concerning these energy resources.

In this connection, on July 23, five other Senators and I called upon the President's Oil Policy Committee to determine at what level our reliance upon imports of crude oil from the Middle East jeopardized our national security. I would like to place my letter in the record of this hearing. And when I receive the response from the Oil Policy Committee, I would like to forward that to the Committee, also.

I applaud the Chairman of this Committee for initiating these hearings on a matter of such vital importance to our nation.

Thank you.

From the Office of Senator John G. Tower, Republican of Texas

Washington.—Senator John G. Tower, R-Texas, offers legislation Wednesday to establish a 12.5 per cent Domestic Exploration Investment Tax Credit to encourage domestic exploration for oil and natural gas.

Tower stressed such encouragement is necessary to insure consumers of adequate energy supplies over the next several years.

"The intent of this legislation is to stimulate investments for exploration of new domestic reserves of oil and natural gas," Tower says in his prepared introductory statement which constitutes a major speech on the plight of the nation's petroleum industry.

"It is intended to help reverse the present dangerous trends which would result in our growing reliance upon insecure Middle East sources of crude oil, and to guarantee the consumer the energy supplies he requires," the ranking Republican of the Senate Banking, Housing and Urban Affairs Committee states.

Following is Tower's prepared speech:

I have warned repeatedly during the past few years that this nation would experience dangerous shortages of energy resources unless corrective actions were taken. Much to my regret and alarm, few such actions have been taken and these few have been inadequate. Consequently, we continue on a collision course with dangerous energy shortages.

The causes and dimensions of these shortages have been abundantly documented in numerous recent reports and statements by representatives of government and industry. Because of these reports, there has been a growing awareness that a serious national energy problem exists.

I would like to focus upon a particular consequence of our energy resource shortages which I find appalling. That is our increasing reliance upon Middle East sources of crude oil to make up the growing deficiency between our ability to produce and our consumer demand.

Estimates of the magnitude of our future reliance on Middle East sources vary But, practically all the reports conclude that during the next fifteen years, we will be forced to rely increasingly upon imports of crude oil from the Middle East to meet larger portions of our burgeoning energy demands.

Secretary of Interior Rogers C. B. Morton reached this conclusion in his June 15 testimony before the Senate Committee on Interior and Insular Affairs. He estimated that by 1985 our total oil consumption would approach twenty-four million barrels per day and that the United States could be forced to import approximately twelve million barrels of crude oil per day from Middle East sources. He concluded that "unless a marked and early improvement occurs in exploration and discovery success and . . . investment in oil producing activities in the United States, there appears little chance that domestic production can keep up with the strong upward trend in demand. . . ." He predicted that by 1985 we will be forced to rely upon the Middle East for at least 45 per cent of our supply of crude oil.

A more pessimistic view of our growing reliance on Middle East oil was presented by Mr. M. A. Wright, chairman of the board of Humble Oil and Refining Company. On May 17, he told the Florida Governor's Conference on the Big Cypress Swamp that "after the next year or so, essentially all of the growth in U.S. petroleum demand will have to be met with imports from the Eastern Hemisphere. Unless we make a substantial effort to increase domestic supplies of all forms of energy, by 1985 foreign imports will supply over half our demand for petroleum and most of this will come from the Middle East." He attached a chart to his statement which showed that by 1985 imports of liquid petroleum products could be 62 per cent of our consumption.

I find these projections by the Interior Secretary and an eminent industrial leader most alarming. Unfortunately, these two projections cannot be considered to be either unique or without foundation.

Increasing reliance on Middle East sources is a totally unacceptable solution to our crude oil supply problems.

We must not allow ourselves to rely on any foreign sources to meet our needs for one of the foundations of our national security. And because of its long history of turmoil and unrest, the Middle East is the least desirable of free world sources.

Our national security objectives regarding supplies of crude oil were officially established in 1959 by Presidential Proclamation No. 3279. These criteria were reaffirmed by the President's Task Force on the "Oil Import Question" in February, 1970, and more recently by the "Report on Crude Oil and Gasoline Price Increases on November, 1970" issued by the Office of Emergency Preparedness in April, 1971.

The criteria are as follows:

1. The need to guarantee supplies sufficient to meet the needs of U.S. military forces and defense industries.

2. The need for a sufficient supply of crude oil and its derivatives to meet essential civilian demands, and sustain economic growth.

3. The need to foster exploration and development so as to insure a depletion of reserves to an extent which would not jeopardize the capability of the petroleum industry to meet future demands, without undue reliance on foreign sources of questionable reliability.

The Cabinet Task Force Report of 1970 also recommended' that imports from Eastern Hemisphere sources not exceed 10 per cent of our domestic consumption.

In summary, then, these objectives explicitly recognize that we must encourage continued exploration in order to insure sufficient producing petroleum reserves to meet both our military and essential civilian needs; that we should maintain a producing capacity sufficient to guarantee future economic growth; and that we should not become overly dependent upon foreign sources of questionable reliability.

These objectives were hammered out over an extended period of time. They have been honored by several administrations. They recognize that petroleum is a vital ingredient to our national defense and to our continued economic health.

I cannot stress strongly enough the importance I place upon the maintenance of these objectives. If the projections of the experts come true, we will have knowingly violated these national security and economic goals. Unless we act now to reverse the current trend, our military capability and our national economic health will be seriously jeopardized, perhaps irrevocably.

Of course, the percentage of our total energy requirements which will be satisfied by oil will probably decrease in the future as other sources of energy are developed. Nevertheless, our need for oil will continue to be tremendous. Secretary Morton, in his June 15 testimony, projected that by the year 2000, oil will still provide 35 per cent of our energy needs, down from the present 44 per cent. This translates into a volumetric increase in crude oil requirements from 15 million to 33 million barrels per day, since our energy needs will rise substantially.

Secretary Morton's projected decrease in the percentage of our energy requirements which will be met by crude oil may be overly optimistic, for his projections are based on assumptions which could be erroneous. The projections assume that we will have developed the necessary technology and machinery by the year 2000 to utilize various exotic means for energy production such as the breeder reactor, solar and thermal cells, oil shale, and coal gassification and liquifaction, to name a few of the possibilities. Past estimates of the speed of development of this type of technology and equipment have been notoriously inaccurate, and we have no basis for assuming the new estimates to be more accurate. Development of this type technology and equipment often requires much more time than at first anticipated.

I can appreciate the difficulty in making such estimates. Many of the problems are unknown and unforeseen at the time of the estimates. But we should be aware that these estimates may be too optimistic. If so, we may be forced to ask crude oil for longer periods of time and in greater quantities than presently estimated.

The essential point is that we are heading into an intolerable situation in which we are becoming increasingly dependent upon Middle East sources to supply our essential petroleum needs and that political realities in the Middle East make this source insecure.

The Middle East has a long history of turmoil and unreliability. I could compile a lengthy list of uprisings which have resulted in the disruption of the flow of oil from this area.

In addition there have been recent events in the Middle East which could make these sources even less secure than in the past.

For example, the Soviet Union has increased its capability to disrupt oil shipments through the Mediterranean Sea. *Time* magazine reported in its June 28 issue that the Soviet Union had dramatically increased the size of its fleet there. At the present time, the fleet of the Soviet Union "very nearly equals" our own, it was reported. This means that our strength in the Mediterranean is being challenged. The Mediterranean sea lanes are of vital strategic importance in the shipment of crude oil.

Another recent event which increases doubts about the reliability of Middle East oil was the signing of the 15-year treaty between the Soviet Union and the United Arab Republic. Dr. Fayez A. Sayegh, a permanent observer of the League of Arab States and a leading spokesman for the Arab world, recently warned that the signing of this treaty represented an indication of further deterioration of Arab-American relations. He stressed that the significant feature of his treaty was that the UAR had abandoned is policy of non-alignment, and he implied that other Arab countries may be tempted to do the same.

Perhaps the single important development which highlighted the insecurity of Eastern Hemisphere oil was the dramatic display of bargaining strength and unity by the members of the Organization of Petroleum Exporting Countries in their recent negotiations with the oil company concessionaires. This organization is often referred to as OPEC, and is composed of the following countries: Abu Ohabi, Gatar, Kuwait, Saudi Arabia, Iraq, Iran, Algeria, Libya, Venezuela, and Indonesia. Nigeria is expected to join soon.

This list includes practically all the major producers of crude oil in the free world besides the United States. The importance of this organization is exhibited by the fact that we presently draw 55 per cent of our total imports, equivalent to about 11 per cent of our total oil consumption, from these OPEC members.

The tough and unified bargaining stance taken by the OPEC countries represented a reversal of several of our traditional concepts concerning Middle East oil.

First, this was essentially the first time that these countries united to bargain for their common good. In the past, these countries had bargained on an individual basis, often exhibiting a lack of trust in each other. Their overall stance had made it relatively easy for the oil companies to bargain effectively with one at a time.

Second, the demands made by the OPEC countries and finally obtained by them were extremely tough. They extracted large percentage increases in their participation in the profits derived from the production and transportation of oil within their own countries.

Third, their main bargaining weapon was the threat of an embargo on all oil shipments from these coutries. This was a most powerful and effective weapon. Until 1970, few believed that any Middle East country would voluntarily reduce or terminate its oil production. Most believed that none of these countries would deprive itself of the substantial revenues derived from this production. But in 1970 Libya stopped producing a sizable percentage of its oil, and the myth was shattered.

In order to appreciate the relative bargaining strength of the OPEC, it is necessary to examine the increased reliance of Western Europe. Japan and the United States on Middle East oil. In 1950, the primary source of energy for Western Europe and Japan was coal. Now over one half of the total energy supplies of these large industrial nations is supplied by Middle East oil. As to the magnitude of the Middle East sources, the ten OPEC countries control over 80 per cent of the known oil reserves in the world.

We presently import only 3 per cent of our needs from Middle East sources. This figure, though small, is deceptive. Middle East oil constitutes 93 per cent of the fuel oil consumed on the East Coast of the United States. And I have already stressed the trend of increasing reliance upon imports from the Middle East to meet future oil deficits. Some areas of the United States are already over-reliant on Middle East oil, and it is now predicted that we shall become over-reliant as an entire nation.

The result of the OPEC bargaining was that the balance of power tipped in favor of the oil exporting countries. Under the terms of the resulting contract oil revenues to these countries will be increased by approximately $8 billion over the next five years. Large portions of this increase in cost to the oil companies will probably be passed to the consumers.

The critical aspect of these negotiations was the use of the threat of embargo on oil shipments from these countries. This threat can, and probably will, be used again. Most of the oil-consuming countries will be powerless to do anything but to capitulate to the demands of the exporting countries.

The United States does not have to cower before threats of embargo. We have enough indigenous oil reserves to satisfy our needs for several decades to come at projected rates of consumption. It has been reliably estimated that there remains to be discovered more oil in the United States than we have yet discovered throughout our history. The U.S. Geologic Survey has estimated that approximately 430 billion barrels of recoverable oil await discovery in the United States. It has been estimated that we will consume an average of 21 million barrels of oil per day over the next 15 years. If this estimate is accurate, we will consume approximately 105 billion barrels of oil over the next 15 years. So, we have adequate undiscovered reserves of oil to meet all our needs.

But, the mere possession of undiscovered oil reserves does not give us a viable alternative to increasing reliance upon Middle East oil. Our undiscovered reserves must be converted into producing oil fields.

Converting undiscovered reserves into producing reserves can be accomplished only through massive investments in exploration. Estimates of the required investments range into the tens of billions of dollars.

Yet, at the present time, our exploration investment is minimal and the level of our domestic exploration activity is at a 28-year low.

The reason for the depressed level of exploration activity can be attributed to the overall negative attitude of the public and government toward the domestic petroleum industry. This negative attitude has been manifested by a combination of government policies which appear to have been especially designed to inhibit and discourage domestic exploration activity rather than encourage it.

For example, the Tax Reform Act of 1969 reduced the depletion allowance from 27½ to 23 per cent. It has been estimated that this placed an additional cost on the industry of approximately $700 million per year. Thus, at the very time when the oil industry desperately needed help, this tremendous tax burden was added. This dampened domestic exploration.

Another example was the attitude of the Administration to the 1970 25-cent per barrel increase in the price of domestically produced oil. Most of the oil community felt that the President's criticism of this modest 8 per cent increase was unwarranted. The costs of seeking and developing oil reserves have been rising at a much more rapid rate than the sale price for crude oil. From 1960 to 1970, the wholesale price of all commodities rose by 16.3 per cent while the price of crude oil rose only 7.6 per cent, according to Department of Commerce figures. Meanwhile, the costs paid by the producers for the services and materials used in exploring for oil have increased. A sampling of costs shows that since 1960 oil field wages have risen by 42 per cent, machinery by 30 per cent, and well casing by 19 per cent. By combining these statistics, we can obtain an indication of the decreased buying power of a barrel of crude oil. Applying the government's price deflaters in order to state crude oil prices in constant 1958 dollars, the real price of crude oil has eroded by 46 cents per barrel, or 16.5 per cent in the past ten years. So, by using various comparisons, the price and the buying power of a barrel of crude oil has substantially decreased.

With this background in mind, imagine the shock of the petroleum community when the President publicly denounced a modest price increase for domestically-produced crude oil.

The industry was further shocked when the President called for a full scale investigation of the price increase by the Office of Emergency Preparedness. The purpose of the investigation was to determine whether this modest price increase was justified on national security grounds. I encouraged the oil industry to take this opportunity to place in the public record the abundant data which would justify this increase. The industry responded well.

The report concluded that the increase was justified on long-term national security grounds, but did so only "reluctantly". There was considerable data to support this conclusion, and I see no reason for it having to be reached "reluctantly".

There are two main negative aspects to this unfortunate episode. First, the President publicly singled out one industry to criticize over a small price increase. This increase fell far short of even maintaining the price of oil on a parity with other prices affecting the industry. A second negative aspect was the grudging attitude of the Office of Emergency Preparedness in reaching its decision reluctantly", which only served to undermine the image of the industry.

Another example of the overall negative attitude which overshadows the oil industry was embodied in the President's "Clean Energy" Message to Congress of June 4. The President is to be complimented for recognizing the existence of a national energy problem. Moreover, he correctly recognized that the energy problem was one which involves all energy resources and must be dealt with as a whole. These were new concepts for the upper levels of government.

But, the President failed to adequately emphasize that for at least the next 30 years the petroleum industry would be supplying over half of the energy consumed in the United States. Rather, he stressed the importance of developing new energy sources. I support the development of new energy sources, but this development will take many years and for the immediate future we must give the attention required for the adequate development of our petroleum reserves.

The petroleum industry needs encouragement if it is to properly supply the tremendous quantities of oil we require over the next 30 years. Yet, the President's message offered only one identifiable incentive to the petroleum industry. This incentive was his direction to the Department of Interior to accelerate the leasing of federal off-shore lands for oil and gas exploration. This acceleration is certainly required. One of our most accessible petroleum reserves may lie under these lands. But more incentives are desperately needed.

In the interest of our nation's well-being, bold, tangible, recognizable incentives are needed to encourage investments in exploration for new reserves of oil and natural gas.

The most important single incentive to the oil industry is adequate price. We must not merely allow "reluctantly" the price of oil to rise. We must encourage the price of domestically-produced oil to rise. And I stress that doing so would be in the long-term consumer interest, for it would insure energy supply.

Dr. Paul W. McCracken, Chairman of the President's Council of Economic Advisers, correctly noted the role played by price. In his testimony before the Senate Committee on Interior and Insular Affairs on June 14, he said that the key issue is to determine the price necessary to bring forth needed supplies of domestic crude oil.

I believe it is evident that the present price is too low. Our producing reserves are declining more rapidly than they are being supplemented. Our surplus producing capacity is now less than our imports. Therefore, our own producing reserves are no longer sufficient to sustain normal consumption should our imports be disrupted. Our energy supply situation is bad and is worsening.

In providing policies designed to bring forth adequate supplies of this essential commodity, we must not be overly cautious. If the remedies we employ are later found to be overly effective in bringing forth supplies of crude oil, we can adjust them. It may very well be that the increases in the price of domestically produced oil may have to be in the order of dollars instead of pennies per barrel. The prospect of price increases of this magnitude should not alarm the consumer. A one dollar increase in the price of crude oil only translates into an increase of 2.3 cents per gallon of gasoline at the pump. I believe the consumer should be willing to pay this small increase to avoid possible rationing or disruption of supplies. I feel confident that price increases of this magnitude will result in increased exploration activity.

Tax incentives encourage exploration, too. Our history has shown that this form of incentive works. We must devise new and imaginative tax incentives designed to stimulate exploration for new reserves of oil and natural gas.

In this connection, I am introducing today a bill which would establish a 12.5 percent Domestic Exploration Investment Tax Credit. This tax credit would reduce a year's income taxes by 12.5 per cent of any money spent that year in exploring for or developing new domestic reserves of oil and natural gas. The tax credit would be a temporary one and would expire automatically ten years from enactment of the bill.

The intent of this legislation is to stimulate investments for exploration of new domestic reserves of oil and natural gas. It is intended to help reverse the present dangerous trends which would result in our growing reliance upon insecure Middle East sources of crude oil, and to guarantee the consumer the energy supplies he requires.

I recognize that revenue-raising legislation must originate in the House of Representatives. However, this legislation should provide a platform from which needed discussion on the subject may emanate.

I urge prompt consideration of this legislation. We must act now to reverse the depressed level of domestic exploration activity so this nation will not be dependent upon insecure Middle East sources for the bulk of our crude oil supplies which are so vital to our national security and our economic health.

STATEMENT OF SENATOR TOWER ON INTRODUCTION OF GAS BILL

Senator Tower. Mr. President, I am introducing today a bill designed to help insure the Nation's consumers of an abundant supply of natural gas.

Natural gas is one of our most important energy resources. At the present time, natural gas supplies approximately one-third of our energy demands. The Interior Department estimates that by 1985, gas will supply 29.5 percent and by 2000, 26.4 percent of our national requirements.

Also, natural gas is the ideal fuel because it pollutes the environment least. Consistent with our efforts to maintain a clean environment, we should also act to provide adequate supplies of this cleanest burning of all fuels.

At the present time the Nation's consumers are faced with shortages of natural gas. We should therefore take the actions necessary to alleviate this critical shortage. The bill I offer today is one such action.

The preamble of this bill states what I believe to be the fundamental concepts concerning natural gas shortages. The essential elements are that these serious shortages are the direct result of price regulation by the Federal Power Commission, and that, therefore, pricing of this vital energy resource must be taken from the FPC and returned to the free market. The bill is designed to relieve the FPC of its current responsibility of setting the price of natural gas.

This deregulation would be accomplished by redefining the term "natural gas company" as used in the Natural Gas Act to exclude the independent producer. Further, pipeline companies would be allowed to include the deregulated price in their cost base without FPC approval. Thus, the FPC would be unable to regulate the price either directly or indirectly.

The responsibility to regulate the price paid to the independent producer was imposed upon the Federal Power Commission by the Supreme Court in the 1954 decision entitled *Phillips Petroleum Company* v. *Wisconsin, et al.* In this decision the Court held that the term in the Natural Gas, "sale for resale," applied to the sale by a producer of natural gas to the pipeline company.

The decision shocked both Government and industry. Most felt that the Court had erred.

The next year both Houses of Congress passed the Harris-Fulbright Act. This legislation would have redefined the term "natural gas company" to exclude the independent producer from coverage by the Natural Gas Act. However, President Eisenhower vetoed this corrective legislation. He said that he did so for reasons other than those pertaining to the merits of the legislation. He made this statement when he vetoed the bill:

> * * * legislation * * * is needed because the type of regulation of producers of natural gas which is required under present law will discourge individual initiative and incentive to explore for and develop new sources of supply.
>
> In the long run this will limit supplies of gas which is contrary not only to the national interest but especially to the interests of consumers.

Others echoed these views.

Unfortunately, but not unexpectedly, these predictions of shortages resulting from FPC price regulation have come true. These shortages are not surprising since the Supreme Court assigned the FPC the impossible task of having to determine "just and reasonable" prices while operating under the confines and restrictions of normal regulatory procedures.

There are certain inherent defects in price regulation by a governmental agency which result in unrealistically low prices and uncertainty in these prices.

For example, price setting by a regulatory agency is by design a slow process. The proceedings established by law are purposefully deliberate in order to assure ample opportunity for notice, a fair and impartial trial and review of the decision.

In setting gas prices, the Commission receives testimony pertaining to the cost of locating and producing natural gas. The statistics relat-

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ing to any 1 year require at least a year to compile and publish. If one adds to this time the several years required by the normal rate proceeding, it is obvious that the statistics upon which rates are based can be completely outdated by the time they take effect. Since costs have been generally rising over the past 17 years of FPC regulation, the years of delay consumed in the normal hearing and court review virtually assured that the prices set by the FPC will be unrealistically low.

The probability of subsequent court review points up another inherent defect in regulatory price setting.

Subsequent court decisions could result in the price being lowered by court order. This has happened in many FPC area rate hearings. This in turn could result in the producer being forced to refund a portion of the revenues received from sales of gas at the prices permitted by a decision.

Thus, the final result of a decision remains uncertain in the minds of producers as to the actual price he will receive for his gas.

And, uncertainty leads to a reluctance to commit the large sums of risk capital necessary to explore for new reserves of natural gas.

These two defects in price regulation have contributed substantially to a steady decline in exploration for new reserves of gas. Consequently, many potential customers are being denied supplies of this ideal, nonpolluting fuel.

Thus, over the long term, the consumer has not benefited by the regulation of the price of natural gas.

Instead of a plentiful supply of a relatively inexpensive fuel, the consumer has been denied the full use of the clean-burning energy resource.

Not only did the low prices depress exploration activity. it also stimulated demand by the consumer. Natural gas under FPC regulation has been a bargain. For example, on a British thermal unit basis, natural gas is priced at about half the price of crude oil. This bargain price has led to expanded uses of natural gas.

These consequences of FPC regulation have led to the present dangerous shortages. In all probability, these shortages will increase. Lead time of from 3 to 7 years is required to find and develop a new gas reserve. Thus, even if exploration activity were dramatically increased this very day, we would not benefit from this activity for at least 3 years.

Natural gas shortages are especially unfortunate. We possess abundant supplies of undiscovered reserves of natural gas. The Gas Supply Committee, an official organ of the Colorado School of Mines, estimated that as of last December 31, this Nation possesses approximately 1,178 trillion cubic feet of gas in reservoirs yet to be discovered. This Nation presently consumes gas at an annual rate of about 22 trillion cubic feet of gas. So, it is evident that we could supply our own requirements from indigenous sources for several decades. Also, as I noted earlier, natural gas pollutes the environment least of all fuels. We should be striving to provide abundant supplies of this clean-burning fuel in an effort to clean up our environment.

As we consider our natural gas problem, it would be useful to examine the FPC brief in the *Phillips* case. The arguments used in that brief apply today. The Chief Justice of the Supreme Court, Warren

E. Berger, participated in arguing this brief as Assistant Attorney General. In this brief, the FPC presented three main arguments against regulating prices for the independent producer. I would like to quote from this brief. It said that the legislative history of the Natural Gas Act:

> * * * plainly reveals Congress' recognition of three functional divisions of the natural gas industry, (1) production and gathering, (2) transportation and sale in interstate commerce, and (3) distribution to local consumers, and a repeatedly reiterated intention to deal only with the abuses resulting from monopolistic control by the pipeline companies of the strategic middle link of the industry, evils revealed by the Federal Trade Commission report of 1935, from which the Gas Act stemmed. The history, however, contains no suggestion that the evils of monopolistic control were prevalent among the independent producers of natural gas.* * *
>
> It is highly significant in itself that the legislative discussions are bare of any mention of even the possibility of imposing federal regulation upon the substantial proportion of the natural gas industry represented by the independent producers and gatherers of gas. In addition, there are affirmative manifestations of Congressional intent *not* to regulate sales by producers and gatherers.

This was the first argument used by the Commission.

The second argument involved the administrative practice of the FPC not to regulate the producers prior to this decision. Quoting again from the FPC brief:

> Beginning with [the] *Columbian Fuel Corporation* [decision] issued two years after the Gas Act was approved, at a time when four of the five Commissioners had been in office both when the Act was passed and when the predecessor bills were under consideration in Congress, the Commission has consistently held that Congress had not delegated to it power to regulate the business of production and gathering....

Quoting from the *Columbian Fuel* case, the FPC brief continued:

> In no case in its history has the commission held that the Act gives it jurisdiction over a company solely by reason of its movement of gas in interstate commerce on sales in interstate commerce for resale, where such movement on sales in interstate commerce take place in the process of production or gathering.

The brief continued:

> Under well-established principles, such consistent refusal by an agency charged with administering a statute to assert a questioned power is a powerful indication that the authority is lacking.

The third argument involved the Commission's expert judgment in defining terms of an act:

> By omitting from the Act a definition of "gathering" or of the elements for fixing the character of "production or gathering" in relation to the Act's coverage, Congress left to the Commission's expert judgment the determination of the term's scope, based upon an appraisal of its specialized meaning in the industry. Many decisions of this Court hold that where the question is one of specific application of a broad statutory term, the function of the reviewing court is limited to ascertaining whether the administrative conclusion has a reasonable basis in law and is supported by the evidence.

These are all cogent arguments today:

Basic conditions of the natural gas industry have not changed significantly since the *Phillips* decision was handed down. Predictions concerning the effect of the *Phillips* decision have come to pass. Shortages presently exist.

Mr. President, this bill is designed to reverse the unfortunate trend which the *Phillips* decision initiated. Action is long overdue, and I urge prompt consideration of my bill.

Pursuant to Senate Resolution 45, there is presently an energy study in process. This study is being conducted by the Senate Interior and Insular Affairs Committee, of which Senator Jackson is chairman. On June 14, Senator Jackson stated in committee hearings that action should be taken in regard to some parts of our energy situation without further study and that the natural gas situation was one such part. I agree.

But, some are opposed to price deregulation. They maintain that with deregulation, natural gas prices will substantially increase and that such an increase would not be in the best interest of the consumer. The important point is, however, that the consumer's best interest has not been served by the past 17 years of FPC regulation. The result of this regulation is that supplies of natural gas have been effectively dried up to the point that many consumers are presently being denied the use of this fuel, and more consumers will be injured as this regulation persists.

I anticipate, and indeed hope, that deregulation will cause some beneficial changes. For example, the price of gas would most probably rise. Artifically contrived pricing distinctions, such as "old-new" and "off-shore-on-shore", would be abolished. The price of gas would be based on B.t.u. content on a competitive basis with other fuels.

Moreover, when a gas purchase contract expired, the producer and the pipeline company would be at liberty to negotiate a new price. These negotiations would take into account the normal factors of the free market such as the availability of gas in relation to demand, the relative ease and convenience of handling and transporting it, and polluting characteristics. I would anticipate that the free market negotiations which take these factors into account would probably result in a reasonable price being paid for this ideal fuel. And this higher, reasonable price would result in increased quantities of natural gas for consumers.

I am certain that by returning the pricing of natural gas to the free market, the necessary amounts of risk capital will be forthcoming to explore for and develop our abundant undiscovered reserves of this ideal fuel.

Then, and only then, will the best interests of the consumer be protected. Any compromise short of complete price deregulation will only result in continued and intensified shortages.

Again, I urge prompt consideration of my bill.

The following letter was sent to each member of the Oil Policy Committee over the signatures of the following members of the United States Senate: John G. Tower, Texas; James B. Pearson, Kansas; Ted Stevens, Alaska; Milton R. Young, North Dakota; Clifford P. Hansen, Wyoming; Henry Bellmon, Oklahoma; and Paul J. Fanning, Arizona.

U.S. SENATE,
Washington, D.C., July 23, 1971.

DEAR SIR: It has been reliably estimated that by 1985, we could be forced to import up to 62 percent of our crude oil requirements from foreign sources. The bulk of these imports would come from the Middle East.

We find this solution to our crude oil supply problems totally unacceptable. We must not drift into a position of reliance on foreign sources to supply this vital ingredient of our national security.

Secretary of the Interior Rogers Morton commented on this matter recently. In a speech before the National Petroleum Council on July 15, he said,

"We have the tremendous potential in undeveloped energy resources of the United States to make ourselves essentially independent of external sources for our future supply. We can certainly limit our dependence upon these sources to a degree commensurate with our national security. In the short term we cannot avoid increasing our dependence upon foreign energy supplies over the next few years because they now appear to be the only available source to fill the supply demand gap. But we should recognize that we are acting contrary to our long range national interests in doing so, and thus make specific provisions for reducing this dependence on foreign sources as rapidly as we can."

The purpose of this letter is to ask you as a member of the President's Oil Policy Committee to urge that the Committee promptly initiate a program designed to reduce this dependency on foreign sources.

One essential element of such a program is the setting of the maximum level of crude oil imports which will preserve our national security interests. At the present time, we import approximately 25 percent of the crude oil and crude oil products consumed in this country.

You may or may not determine that present import levels are excessive. But, the determination should be made consciously. We must not simply drift.

We believe that present import levels are excessive and that these excessive imports have contributed to the decline in domestic exploration activity. As a result of this decline in domestic exploration activity, we have been consuming crude oil at a more rapid rate than we have been adding to our producing reserves. Consequently, it has been estimated that by 1973, we will be forced to rely on Middle East sources for most of the increases in our petroleum demands.

Further, if our foreign sources of supply were cut off, we could be forced to ration our petroleum supplies since we would not have any spare capacity.

As you can see, this is a dismal picture. We can think of few, if any, matters which would require your attention more urgently than this distressing situation.

We would appreciate your evaluation of this suggestion and, if you concur with us, your estimate as to when a determination can be made.

Sincerely,

JOHN G. TOWER.
JAMES B. PEARSON.
TED STEVENS.
MILTON R. YOUNG.
CLIFFORD P. HANSEN.
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CONTROL OF SULFUR OXIDE EMISSIONS

IN

COPPER SMELTING

UNITED STATES DEPARTMENT OF THE INTERIOR

Rogers C. B. Morton, Secretary

BUREAU OF MINES

Elburt F. Osborn, Director

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CONTROL OF SULFUR OXIDE EMISSIONS IN COPPER SMELTING

SUMMARY AND CONCLUSIONS

The domestic copper producing industry has been challenged with the formidable task of reducing the amount of sulfur oxides and other pollutants emitted from sulfide smelters. This challenge has been imposed by legislation for governmental control over air pollution. Stringent standards for both ambient air quality and allowable emissions have been proposed and are already in effect in some States.

The industry is making a valiant attempt to comply with the standards within the 3-year period that has been established but there are serious doubts that the job can be accomplished. Currently, there is a wide range of opinions concerning what can be done and the minimum time in which an acceptable solution to the problem can be achieved while still maintaining a strong competitive position of the United States as a primary copper producer.

A capital investment of hundreds of millions of dollars will be required to make necessary changes in present smelters and to add on the additional plants for sulfur removal. Incremental operation cost increases, which will be reflected as increased price of the metal, will be at least 3 cents per pound of copper.

Production of sulfuric acid is the only well-established process for removing sulfur dioxide from smelter gases. Most smelters are planning installation of acid plants. Unfortunately, this is only a partial answer. Acid plants are only feasible on gas streams containing more than 4 percent sulfur dioxide, and with current smelting practice can recover only 60 percent of the total sulfur in the smelter feed. Flash or electric furnaces or replacements for the reverberatory furnace would increase the strength of the offgas and allow recovery of additional sulfur; but not enough to meet the 10 percent emission standards that have been made law in Arizona, Nevada, Montana, and the Puget Sound area. The situation is further complicated by the fact that the smelters are not near major markets for acid. Disposal of excess acid and ponding will be required, with attendant additional cost.

Some form of neutralizing scrubbing system will be employed to absorb the sulfur oxides from the weak gases. Wet lime or limestone scrubbing are most likely candidates since they are flexible and applicable to variable gas flows and sulfur dioxide concentrations. A tandem system, perhaps scrubbing with first limestone followed by caustic scrubbing, may be required. Such processes are not considered "proven" technology, however, and difficulties have been encountered in pilot plant operation, even with gases very low in sulfur oxides. It is doubtful that smoothly operating scrubbing systems will go on stream in less than 5 years.

The Asarco brimstone process has been operated on a semicommercial scale to produce sulfur from gases containing more than 5 percent sulfur dioxide. The only method for producing elemental sulfur from smelter gases that has been sufficiently tested to evaluate are modifications of this process. The process uses natural gas and catalysts to produce sulfur which is recovered by electrostatic precipitators. On rich gases this process is claimed to be capable of 95 percent recovery. The use of natural gas may pose some restriction for adopting this process. The process is being investigated jointly by two copper companies. About 3 more years of development work appears necessary before a commercial plant can be built.

Two processes have been investigated for separating and concentrating sulfur dioxide by adsorption scrubbing. They have been developed to a semicommercial scale but both have serious drawbacks. The Cominco process uses a scrubbing solution of ammonium sulfite-bisulfite; the Asarco process uses anhydrous dimethyaniline. Both are regenerative systems but reagent makeup is costly; hence, operating costs are higher than standard acid production. The Cominco process produces a 30 percent sulfur dioxide for subsequent conversion to acid or elemental sulfur and an ammonium sulfate byproduct for which there is a limited market. The Asarco process yields concentrated sulfur dioxide for which the market is also limited.

Investigations are being continued on many other processes and techniques, but it is estimated that none can be brought to the engineering design stage within 5 or 6 years.

There is serious doubt that imposition of 10 percent emission standards in addition to ambient air standards is a realistic solution to the problem. The recently proposed tax on sulfur emissions also is of dubious merit and would place additional financial burdens on an industry already staggered by cost of capital investment for emission control.

The Bureau of Mines is reasonably assured that given the necessary time for development and demonstration, an engineering capability will emerge that can cope with smelter gases in an efficient and effective manner. In the meantime, it is essential that both industry and Government marshal all resources available to develop the needed technology, and to formulate time schedules that reflect a reasonable balance between what must be done eventually and what can be done now.

INTRODUCTION

Restriction of the amount of sulfur oxides, particulate matter, and other pollutants that can be discharged into the atmosphere by copper smelters is no longer speculative. The Bureau of Mines recognizes the need to make a factual assessment of the air pollution problem related to copper sulfide smelting. The purpose of this assessment is to review objectively the overall smelter pollution problem, the existing or proposed regulations for controlling smelter pollution, the magnitude of the problem as it affects the domestic copper industry, the state of the art of sulfur oxide emission control technology, and the efforts being made by industry to develop acceptable technology for abating or controlling smelter pollution.

The implications of the problem are shown by the fact that supply-demand forecasts for copper in the United States consistently show demand exceeding supply. The United States leads the world in both production and consumption, and currently the value of copper produced from domestic ores approaches $1.5 billion annually. However, the extent to which it meets its future requirement from domestic sources is likely to decrease. As one of the key commodities in this industrial economy, domestic copper production growth should be encouraged, even recognizing that imports will have to supply an increased percentage of future United States demand. Cost reductions at every stage from exploration through fabrication will have to not only accomodate the continuously decreasing tenor of raw materials but permit effective competition with foreign operations. Any technologic advance that contributes to cost reduction is eagerly sought. Conversely, anything that increases cost is a subject of grave concern.

The supply of a host of byproducts and coproducts depends upon the rate of copper production and the technology of processing and refining. In one instance, production of copper from the porphyry deposits in the western United States provides the only domestic source of rhenium, a metal of increasing importance as a catalyst for reforming gasoline.

Collectively, the 1969 value of byproducts and coproducts recovered from domestic copper operations amounted to nearly $140 million. Any reduction in domestic copper smelting could have an adverse effect on supply of these important elements and on the contribution of the copper industry to the total economy.

DIMENSION OF THE PROBLEM

Air Pollution Regulations

Air pollution problems created by smelting sulfide copper ores and concentrates are not new. Rather, they date back to the very inception of smelting. Nor have they been ignored by either the industry or the public. The history of copper smelting is replete with examples of legal actions instituted by individuals against smelter operators, in which claims for damage to property were the basis of action. Generally, these were settled by purchase of affected land or cash payment to the claimant. Prevention was sought by building high stacks that dispersed the fumes in a manner that obviated any gross damage to far-lying property. A balance was reached, over the years, in which industry and the public were reasonably well satisfied with the accords that were reached.

In efforts to circumvent the smelting step, research has been conducted over the years to develop methods other than smelting for converting copper sulfide ores and concentrates to metal. However, none of the proposed processes have proved economically competitive with conventional pyrometallurgical practices.

With the growth in industrial activity throughout the Nation and the proliferation of automobiles, air pollution throughout the United States became a problem, primarily in the cities. This led to a general demand for some sort of national control over air pollution. Emissions caused by smelters were only a small part of the problem, but the nonferrous smelting industry was inevitably drawn into the larger problem because the smoke and sulfur-bearing gases contribute to the total air pollution burden.

The demand for some form of national control over air pollution generally led to the enactment of a series of Federal statutes dating back to a basic law of 1953. These have since been amended and revised several times. The principle was established that the Federal Government promulgates the basic regulations, but that the States bear the burden of enforcement, based on their own laws and regulations. In all cases, however, State regulations must at a minimum conform with the Federal regulations, but they can be more stringent.

Originally, the authority for Federal investigation and regulation was placed in the hands of the National Air Pollution Control Administration (NAPCA) of the Department of Health, Education, and Welfare. As the problem of air pollution from nonferrous smelters posed a problem that was unique, NAPCA negotiated a contract for technical services with Arthur G. McKee & Company in December 1967, to prepare a comprehensive evaluation of the problems existing in this industry as related to air pollution. A report on this subject was published in June 1969.

Late in 1970, the general reorganization of Federal pollution-related functions placed the national problem of air pollution under the direct authority of the Office of Air Programs of the Environmental Protection Agency (EPA). Section 109 of the Clean Air Act, as amended December 31, 1970 (Public Law 91-640), directed the Administrator of EPA to establish national primary and secondary ambient air quality standards. Proposed standards were published in the Federal Register, v. 36, No. 21, January 30, 1971. After hearings, the final standards were issued April 30, 1971, and constitute the criteria on which future State and local regulations must be based. Each State is required to adopt regulations and submit implementation plans to EPA by January 30, 1972. Within 4 months of that date, or by May 30, 1972, EPA will either approve or disapprove each State plan. This schedule is fixed for primary ambient air standards, but may be extended an additional 18 months for secondary standards.

In the case of a plan implementing a primary standard, compliance must be as expeditious as possible, and in no instance later than 3 years from the day of approval, or May 30, 1975. Within a reasonable time, plans for secondary standards must follow. Extension beyond May 30, 1975, for implementing a primary standard may be granted by EPA if due diligence in complying has been shown.

In the meantime, the various State and local agencies concerned with air pollution have been engaged in proposing and establishing regulations of their own. As might be expected, they have differed widely, both as to scope and degree of regulation. Some are comprehensive, others are meager in detail. Generally, the Federal standards are more strict than those that have been established by State and local authorities. These standards probably will have to be revised depending upon the final Federal standards that are established.

Current Federal standards refer only to ambient air. Two sets of standards are proposed. Primary standards, to protect the public health, define how clean the ambient air must be so that it will not be harmful to human health. Secondary standards to protect the public welfare, define how clean the air must be in order to protect against the known or anticipated effects of air pollution on property, materials, climate, economic values, and personal comfort.

The proposed and established State and local standards generally concern both ambient air quality and actual smelter emissions. Ambient air standards refer to pollution in the air at the property boundary of the smelter operation, generally at ground level. As with the Federal standards, they are usually designated as maximum sulfur dioxide concentrations for various time intervals. Emission standards are defined as the maximum percentage of the total sulfur feed to a smelter that may be discharged to the atmosphere. Based on standards proposed by EPA, several States have established a 10 percent limit.

State and local standards, on the whole, have provided for accomodating fluctuation in smelter operation. They have allowed for short periods of time in which ambient air limits for sulfur dioxide may be high, provided that the average over a longer period of time is within prescribed limits of tolerance. Conversely, emission standards based on sulfur burden to the smelter tend to be dogmatic in that they disregard the alternatives for achieving an acceptable sulfur oxide concentration in the ambient air. Further, they fail to consider how the unique or unusual characteristics of each smelter relate to local or regional pollution.

It generally has been accepted by State and local regulatory agencies that time must be allowed for full compliance with any standards because of the technological problems that must be solved, and the lead time required to construct the necessary air pollution control facilities. For the most part, this has been set at a minimum of 3 or 4 years. However, this time allowance is contingent upon serious, continued action on the part of the smelter operators to change their operations to meet set standards.

Proposed and established National, State, and local standards, as they apply to sulfur emissions at copper smelters, are summarized in the Appendix.

Domestic Copper Production

Significant production of copper began in the United States about 1845. Until World War II, production exceeded consumption and some copper was exported. About 1940, the United States shifted from a net exporting nation to a net importing nation. Because United States production is inadequate for all needs, copper is designated as one of the strategic materials to be stockpiled for United States protection in case of war. Return of the United States to a position of self-sufficiency is not likely under foreseeable conditions, and further deterioration of the domestic copper mining industry could be disastrous in times of emergency. The domestic copper industry has been confronted with technical and economic problems relating to all phases of the industry--resources, mining, extraction, marketing, and pollution.

The primary ores and concentrates produced in the United States are smelted in 16 smelters owned by 8 companies. There are 8 smelters in Arizona, and one each in the States of Michigan, Montana, Nevada, New Mexico, Texas, Tennessee, Utah, and Washington. Copper processed in 1970 by the smelters in Arizona was 804,158 tons, including 12,580 tons from scrap. Copper processed by the smelters in all other States in 1970 was 856,416 tons, including 12,956 tons from scrap and 36,072 tons from foreign concentrates.

The major copper producing countries of the Free World, other than the United States and Canada, are emerging nations which have a critical need for employment that the copper smelting and refining industry provides. Also, these countries are in need of hard currency exchange credit which they obtain by the export of copper.

Prior to 1970, United States smelting capacity was greater than required for treating domestic materials and the excess capacity was used to treat substantial quantities of foreign crude materials. This condition was reversed in 1970. In mid-1970, a major copper smelting company, which provides custom smelting service, notified all customers that new pollution restrictions made it necessary to invoke the force majeure clause in their contracts to the extent of reducing the amount of ore and concentrates accepted by 15 percent.

The demand by domestic producers for smelter capacity exceeded availability, and arrangements were made to treat domestic concentrates in foreign smelters. The copper content of domestic concentrates exported for treatment increased from 979 tons in 1969, to 58,450 tons in 1970. Although this increase in exports cannot be attributed solely to pollution regulations, a reduction in effective capacity at domestic smelters cannot but contribute to the problem when demand for capacity is high.

Current smelting technology has been practiced by the domestic copper industry for about 70 years, and during this period smelter pollution has not been subject to governmental regulations. Thus, with the passage of Public Law 91-640, the copper industry within a relatively short period of time was faced with undertaking extensive engineering modifications and construction programs to install processes in its smelters capable of reducing sulfur oxide emissions to comply with proposed or established criteria.

Because of the extent of the engineering changes that must be made and the uncertainty of the best technology for achieving sulfur oxide containment, time to resolve these problems will be required.

Copper Smelting Practice

Copper, as it occurs in ore, can be classed as three main types--native copper, oxide copper, and sulfide copper. Most of the world copper production comes from low-grade sulfide ores from which the sulfide copper minerals are readily concentrated by flotation. The finely ground sulfide flotation concentrates consist of copper sulfides, iron sulfide, and gangue. The purpose of smelting is to separate the copper from the iron, sulfur, and gangue. The thermodynamic relationships between these principal ingredients form the basis for the three major steps, which are: roasting to remove excess sulfur; melting in a reverberatory furnace to remove gangue and to form a copper-iron-sulfur mixture called matte; and oxidation of the matte in a converter to form a separable iron slag and to burn the sulfur away from the copper. Each of these steps generates sulfur oxides. The separation of sulfur from copper by oxidation to form sulfur dioxide gas is the only currently known method for producing copper from sulfide ore at economically competitive costs.

Two types of equipment are used for roasting: multiple-hearth and fluosolids roasters. Both are autogenous in that no fuel is required other than the small amount needed to initiate combustion at startup. The heat from the oxidation of the sulfur and iron are sufficient to sustain the process. As only minor amounts of fuel are required, the offgases are not diluted by fuel combustion gases and emerge from the furnace containing from 3 to 12 percent sulfur dioxide.

The capacity of a multiple-hearth roaster ranges from 150 to 200 tons of concentrates per day. The fluosolids roaster, a more recent development, has higher capacity; usually only one unit is required to handle 1,200 to 1,500 tons of feed per day. Offgas containing more than 4 percent sulfur dioxide is common.

Calcine, if roasting is practiced, or unroasted concentrates (green feed) are smelted in a reverberatory furnace, fired with oil, gas, or pulverized coal. The large volume of gas generated by the burners produces an offgas containing only a dilute concentration of sulfur oxides, the strength of the offgas depending on the sulfur in the feed material, the fuel, and the furnace operation.

When sulfur content of the smelter feed is high--more sulfur than copper--roasting to reduce sulfur content before melting is attractive, and if practiced may reduce the amount of sulfur discharged from the reverberatory furnace to less than 10 percent of the total feed sulfur. When less sulfur than copper is in the feed, roasting is not practiced, and the sulfur discharged in the reverberatory offgas may be as high as 30 percent of the total sulfur.

The sulfur dioxide content of reverberatory furnace gas generally ranges from 0.25 to 1 percent when melting calcines or low sulfur-bearing feed. When concentrates rich in sulfur are fed directly to the furnace, the sulfur dioxide content of the gas may be as high as 2.5 percent.

The process of removing iron and sulfur from copper in a converter is a controllable operation, but, unlike the roasting and smelting steps, is a batch process. The sulfur dioxide content of the offgas may range from 3 to 12 percent during the converting cycle.

When multiple converters are in use, the cycles can be staged to hold the strength of the combined offgases within limits suitable for sulfuric acid production. The converter furnace is an open furnace and containment of the gases is difficult. Some of the leakage can be prevented only at the expense of diluting the offgas by drawing air into the system.

Smelter Gas

Handling the gases discharged from roaster, reverberatory, and converter furnaces at a smelter presents major engineering problems. A large volume of hot gas, containing rock dust and other particulate material, must be cooled, cleaned, and conducted to the stack where it can be vented.

The construction and operation of the extensive gas handling system is a high cost item in operating a smelter. Changes in this type of equipment are particularly expensive because the corrosion rate is high and connections and alterations are difficult if not impossible to make without complete replacement.

In the past, the smelter stack was considered adequate for dispersing the smoke to harmless levels. As the current regulations to govern smelter emissions are more stringent than previously thought necessary by the industry, the smelter operators are now forced to consider implementing processes for reducing sulfur content of the gases drastically before they are discharged into the atmosphere.

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The visible part of the plume that characteristically marks the smelter as an air pollution source consists mainly of sulfur trioxide mist. Sulfur trioxide represents only a small fraction of the total sulfur evolved; generally less than 5 percent. Consequently, full compliance to an emission standard would conceivably be attained with little if any reduction in the visible part of the stack plume. As in the past, the visible sulfur trioxide mist poses a serious public relations problem for the smelter operator, particularly when the smelter is located near heavily populated areas. It is conceivable that local air pollution regulations for sulfur could be enacted that would far exceed requirements because of the visible nature of the plume.

CURRENT PRACTICE FOR SULFUR DIOXIDE CONTROL

There currently are three methods in use for reducing the sulfur dioxide concentration in the atmosphere surrounding a copper smelter. All smelters use one or a combination of these methods. Although no smelter can presently meet the 90 percent removal standard, all can approach, if not comply, with proposed ambient air quality standards. The degree of compliance depends on the location of the smelter, meteorlogical conditions, sulfur content of the concentrate being smelted, and the smelting practice.

Of the three methods, the tall stack is the simplest. It discharges the sulfur dioxide at such heights that the gas is diluted and dispersed into the atmosphere. The trend has been toward taller and taller stacks. For example, the average height of stacks for coal-burning power plants in the United States has been reported to have increased from slightly less than 250 feet in 1960 to more than 600 feet in 1969. Even now, the International Nickel Company of Canada is constructing a stack 1250 feet tall at Copper Cliff, Ontario, to meet the air quality standard of the Ontario Air Management Branch.

Even if other processes for removing sulfur dioxide from the smelter gas are adopted, the tall stack will still be an important control method. It is not likely that any process will emerge in the near future that will allow discharge of the tail gas at ground level.

The second method of reducing the sulfur dioxide concentration in the atmosphere couples the contact sulfuric-acid plant and the tall stack. Production of sulfuric acid by the contact process is well established and is the only commercial process now being used at copper smelters to remove sulfur dioxide from stack gases. Acid plants require at least 4 percent sulfur dioxide in the feed gas and are not economical for treating the more dilute smelter gases. The requirement of strong gas for acid production is one reason why many processes have been investigated for concentrating the sulfur dioxide from dilute gas streams.

With current smelting practice, production of acid from the roaster and converter gases can reduce the sulfur oxides emitted to the atmosphere by 50 to 60 percent.

The third method of controlling the sulfur dioxide discharged to the atmosphere is production curtailment when adverse weather conditions prevail. This method, referred to as "closed-loop control" by the industry, employs several sulfur dioxide monitoring devices which are strategically located in the area surrounding the smelter. These monitoring devices sense the rise or fall of sulfur dioxide concentration in the atmosphere and report to a center where the information is analyzed with respect to the short term weather forecasts. Based on this information the smelter operation is adjusted to regulate the discharge of sulfur dioxide to stay below the allowable level of contamination.

In combination, the tall stack, acid production, and production curtailment by monitoring provide a considerable degree of control for maintaining the atmospheric sulfur dioxide concentration at low levels.

STATUS OF TECHNOLOGY FOR REMOVING SULFUR DIOXIDE FROM SMELTER GASES

The distinction between the two types of air pollution control standards--air quality and emission--are important considerations when examining the state of the art for controlling smelter gas discharge. The air quality standard permits alternatives for the smelter operator to meet the standard; the emission standard demands removal of a specified percentage of sulfur in the smelter feed.

In 1958 the U. S. Bureau of Mines published a compilation of information on the chemistry of sulfur dioxide, emphasizing reactions having application to the problem of air pollution. The publication also reviewed both existing and proposed technology for removing sulfur dioxide from industrial waste gases. Although the publication was oriented toward dilute gas streams from coal burning power plants, technology for treating richer gas streams, such as those from nonferrous smelting, was also reviewed.

In 1969, Arthur G. McKee & Company prepared an evaluation of the problems existing in the nonferrous smelting industry for controlling sulfur dioxide air pollution. This report included a review of the technology for removing sulfur dioxide from smelter stack gases, and concluded that there were only five of the host of proposed processes that had been sufficiently tested with enough data made available so that costs could be estimated for application to a range of smelter conditions. The five processes were the contact sulfuric acid process; the Cominco absorption process; the Asareo process for producing elemental sulfur; the wet lime scrubbing process; and the wet limestone scrubbing process.

A few other processes are currently being developed and may eventually prove superior to those cited by the Arthur G. McKee & Company. Of these new processes, the citrate absorption process, under development by the Bureau of Mines, appears attractive, especially for lean gas streams.

Processes for removing sulfur oxides from gas streams are based on: (1) conversion of SO_2 in gas to SO_3 for production of H_2SO_4; (2) separation and concentration of SO_2; (3) reaction of SO_2 to yield solid sulfur compounds; and (4) reduction of SO_2 to elemental sulfur. Process selection will be dictated by economic conditions for sulfur byproduct disposal and by variation in the nature of the offgases such as sulfur dioxide concentration, impurities carried over from smelting operations, and fluctuations in gas flow rates. Other factors, both economic and noneconomic, such as geographic location, nearness of markets for sulfurous products, available land for product disposal, and potential water pollution problems can and will influence the choice of method for controlling emissions.

Conversion of SO_2 to SO_3 for Acid Production

The contact sulfuric-acid process is the only well-established chemical process for removing sulfur dioxide from smelter gases. Basic steps in the process are shown schematically in Figure 1.

After the smelter gas has been cleaned of particulates, it is cooled and cleaned, and the clean gas is dried with strong sulfuric acid. The sulfur dioxide in the dry gas is then oxidized to sulfur trioxide in a catalytic converter. Finally, the sulfur trioxide is absorbed in strong sulfuric acid to yield the product of the plant. The tail gas is treated to remove droplets of acid and normally is vented to the atmosphere. Tail gases will contain from 0.2 to 0.5 percent sulfur dioxide. In some cases the tail gas must be treated to lower the concentration of sulfur dioxide before discharging.

Strong gas is a prime consideration for acid production, though this is not a technological limitation but a matter of economics. Acid plants can be designed to operate on gases containing only a fraction of a percent of SO_2, but they are too expensive to build and operate under normal practice. The normal economic minimum concentration of SO_2 in an acid plant's feed gas is 4 to 5 percent.

The major factor limiting production of sulfuric acid from smelter gas is marketability of the acid. Eighty-seven percent of the sulfur consumed in the United States during 1969 was converted to sulfuric acid, an intermediate product, prior to its end-use consumption by industry. The sulfur sources for the 200 acid plants engaged in this conversion were: Frasch and recovered sulfur, 89 percent; nonferrous smelter gases, 6 percent; and pyrites and miscellaneous sources, 5 percent. The acid plants using native sulfur almost invariably are located close to the centers of sulfuric acid consumption, as it is cheaper to ship crude sulfur than sulfuric acid. The geographical distribution of sulfuric acid production by percent was: Southern States (except Florida), 36 percent; Florida 27; North-Central States 15; Western States 12; and Northeastern States 10.

Over 95 percent of all sulfur discharged to the atmosphere as oxides from nonferrous operations is from smelters west of the Mississippi River and copper smelters account for the major portion of this figure. If the acid cannot be consumed in production or sold at nearby markets, the cost of making and disposing of the acid must be added to the smelting cost.

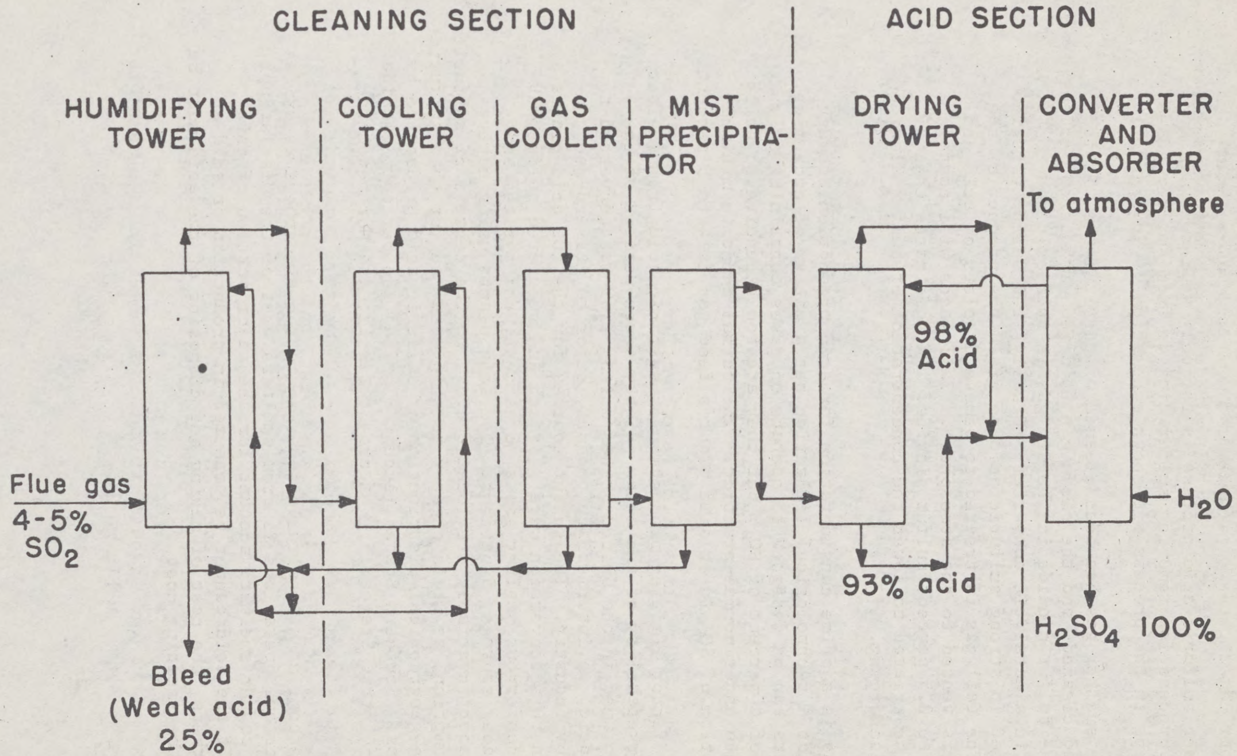

FIGURE 1. - Contact Sulfuric Acid Process

To safely dispose of sulfuric acid, it must first be neutralized with lime or limestone--to produce an inert compound--gypsum--which is then impounded. If cheap land is available and near the smelter, impounding would not pose too serious a problem. If not, disposal could eliminate acid production as a control process for sulfur dioxide emissions.

Neutralization of the acid will entail a series of costly steps. These include mining, hauling, and grinding the limestone before it is mixed with the acid. The limestone must be finely ground, otherwise excessive consumption of limestone is caused by occlusion, formation of calcium sulfate on the limestone particles. Even with efficient utilization of the limestone, more than 3 pounds would be required for each pound of sulfur removed from the smelter gas. If the limestone is converted to lime before neutralization, then the additional cost of calcining must be included in the disposal cost.

Production of sulfuric acid will not solve the pollution problem for all smelters.

Separation and Concentration of SO_2

Several cyclic absorption systems have been developed and used for separation and concentration of sulfur dioxide from gas streams. The concentrated sulfur dioxide can be used as such, it can be converted to acid, or be reduced to elemental sulfur. The simplest procedure for regenerating the absorbent employs stripping with steam, but chemical regeneration methods are also used. The choice of absorbent is dependent upon the initial concentration in the gas stream. Those absorbents that afford a favorable equilibrium for removal of sulfur dioxide at low concentrations tend to require excessive amounts of steam for regeneration. On the other hand, absorbents having equilibria and capacities favorable for recovery of sulfur dioxide at high concentrations in the gas stream are at a disadvantage in the recovery from dilute streams. There are two principal regenerative absorption processes in commercial use for separation and concentration of sulfur dioxide from smelter gases. One uses a solution of ammonium sulfite-bisulfite as the absorbent, and the other uses anhydrous dimethylaniline as the absorbent. Both have found only limited application.

As developed by the Consolidated Mining and Smelting Company of Canada, Ltd. (Cominco), the ammonium sulfite-bisulfite absorption process employs chemical regeneration with sulfuric acid to release sulfur dioxide and form ammonium sulfate. A simplified flowsheet for the process is shown in Figure 2.

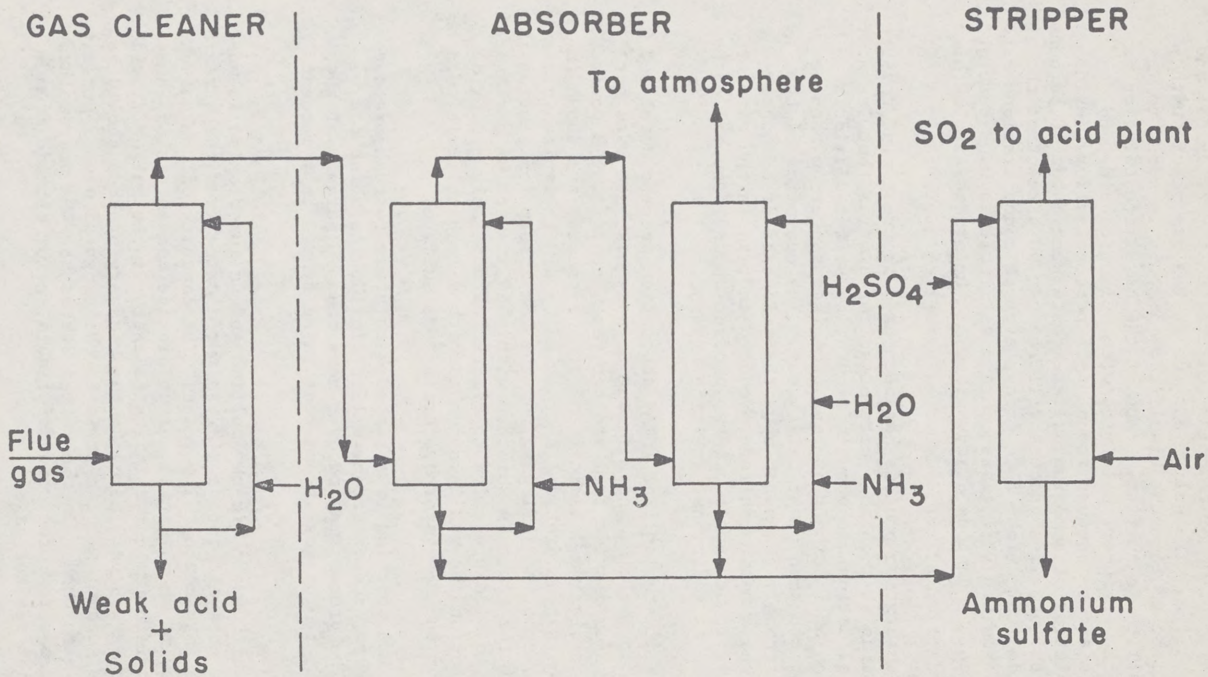

FIGURE 2. - Cominco Absorption Process

Sulfur dioxide, free of sulfur trioxide and particulates, is scrubbed by a solution of ammonium sulfite, sulfur trioxide, and ammonium bisulfite. The sulfur dioxide in the gas reacts with ammonium sulfite to form the bisulfite. Ammonia is added to convert bisulfite to sulfite. Part of the bisulfite solution is diverted to the stripper, acidified with sulfuric acid, and stripped with air to produce around a 25 percent sulfur dioxide gas and a solution of ammonium sulfate containing about 10 percent of the feed sulfur. The process will recover 90 percent of the sulfur dioxide from dilute flue gases, even at concentrations as low as 0.5 percent. Tail gases contain as little as 0.03 percent sulfur dioxide. A serious disadvantage of the process is the high cost of ammonia.

The Cominco absorption process has been used to treat zinc roaster gases containing as much as 6 percent sulfur dioxide, but its most important application has been in recovering sulfur dioxide at concentrations of 1 percent or less from lead sintering machine gases or sulfuric acid plant tail gases. The economics of the process are strongly dependent upon the existence of adequate markets for the ammonium sulfate produced and, as in the case of sulfuric acid, if no market exists, production and disposal costs must be viewed as additional smelting expense.

The anhydrous dimethylaniline (DMA) absorption process developed by the American Smelting and Refining Company has been used for recovering sulfur dioxide from smelter gases containing 3 percent or more sulfur dioxide. Basic steps of the process are shown in Figure 3. The sulfur dioxide is absorbed by dimethylanine in a bubble-cap tower. The tail gas from the DMA absorption section in the bottom of the tower is scrubbed with a dilute sodium carbonate solution in the middle section to remove residual sulfur dioxide. In the top section the gas is scrubbed with dilute sulfuric acid to remove most of the DMA vapor by forming DMA sulfate.

The pregnant DMA solution is stripped with steam to regenerate the absorbant and to produce strong sulfur dioxide gas which can be liquified. The process may recover more than 90 percent of the sulfur dioxide from a gas stream containing from 2 to 4 percent sulfur dioxide.

The equilibrium between dimethylaniline and sulfur dioxide is unfavorable for economic recovery of sulfur dioxide from gas streams containing less than about 2 percent. The capacity of the solvent is good, however, when initial sulfur dioxide concentrations are high. The equilibrium curve indicates that, if the sulfur dioxide concentration were 8 to 9 percent, the recovery process should be markedly more economical than it is in the range of 4 to 5 percent, where it has been used. In the United States the DMA process has found limited use for production of liquid sulfur dioxide from lead and copper smelter gases.

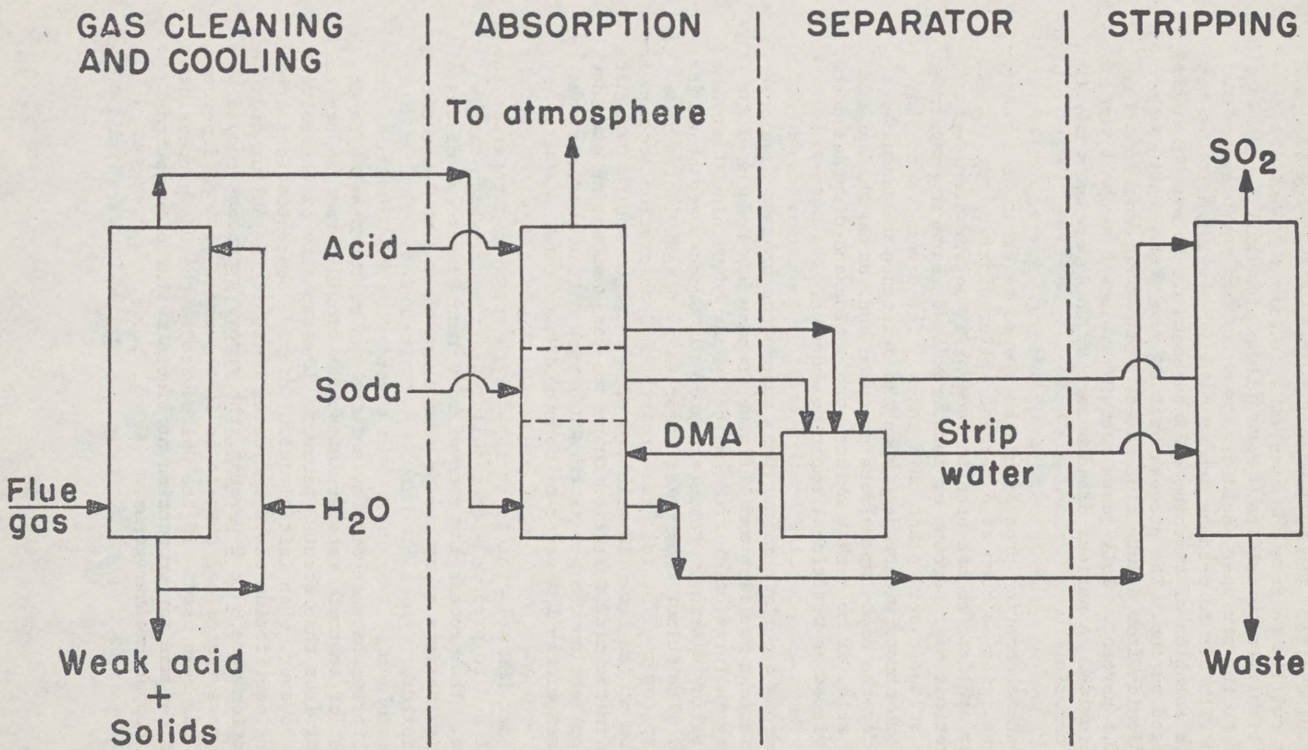

FIGURE 3. - DMA Process (Asarco)

Another process proposed for smelters to concentrate sulfur dioxide is the Wellman-Lord Process. In the absorber section the gas is contacted with a sodium sulfite-sodium bisulfite solution which absorbs the sulfur dioxide to form additional bisulfite. The enriched solution is then boiled by indirect steam heating in an evaporator-crystallizer to decompose the sodium bisulfite solution into a wet gas of sulfur dioxide and steam and a precipitate of sodium sulfite crystals. The resulting slurry containing the precipitates is centrifuged. The solids are finally dissolved with water for recycling. Part of the liquor from the centrifuge is returned to the evaporator for solids-density control. The gas passes through a condenser to concentrate the sulfur dioxide. This process is currently being used on the tail gases of the Olin Corporation's sulfuric acid plant at Paulsboro, New Jersey.

Application of the Wellman-Lord process to smelter gas is only speculative and cost estimates recently published are discouraging.

A variation of reacting sulfur dioxide with an absorbent has been developed by Chemical Construction Corporation and Basic, Inc. In this process, a slurry of magnesium oxide is used to remove sulfur dioxide from gas streams in a venturi scrubber. The magnesium sulfite product is then decomposed thermally to yield concentrated sulfur dioxide for acid production and magnesium oxide for recycling. A pilot plant to test the absorption and decomposition steps of this process is being constructed at Boston Edison's Mystic Station No. 6 power plant. No data are available to evaluate application of the process to copper smelter gases.

Because the market for sulfur dioxide as an end-product is very limited, accounting for only 1 percent of the domestic consumption of sulfur, processes that separate and concentrate sulfur dioxide must be considered as merely preliminary steps to obtain suitable feed for the production of acid, elemental sulfur, or inert sulfur compounds for disposal.

The Cominco and Asarco DMA processes have found limited application but have not been demonstrated as viable processes for treating large volumes of dilute copper smelter gas. It is doubtful that either could be developed and engineered to a scale for implementation at an operating smelter in less than 5 years. The fruition of other processes that separate and concentrate sulfur dioxide will be several years later, perhaps as long as 10 years.

Reaction of SO_2 to Yield Solid Sulfur Compounds

Typical of the processes for reacting the sulfur dioxide gas streams to form solid sulfur compounds are the lime and limestone wet scrubbing processes that yield waste lime compounds, as shown in

Figure 4. In the lime wet scrubbing process, burnt lime obtained from limestone is slaked and the slurry used to absorb sulfur dioxide from the gas stream. The sulfur oxides are removed as calcium sulfate and calcium sulfite which can be separated by thickening. The sludge must be discarded to impoundments. Wet limestone scrubbing is the same except that finely ground limestone is slurried instead of lime. Wet limestone scrubbing is not as efficient as wet lime scrubbing and, in addition, may not be suitable for gases deficient in oxygen or carbon dioxide. It has been proposed that a high percentage of recovery could be obtained by operating the two scrubbing systems in series; the tail gas from limestone scrubbing would be treated by a lime scrubber before discharging.

Preparation of the slurry will entail all of the costs cited for preparing lime or limestone for neutralizing excess sulfuric acid; mining, haulage, grinding, and for lime calcining. Likewise, disposal of the final product will pose similar problems. For smelters located in desert regions, water losses by evaporation may seriously limit application of wet scrubbers.

During the last few years both wet and dry lime and limestone scrubbing have been under investigation for removing sulfur oxides from the stacks of power plants burning high-sulfur coal. Troubles encountered have included buildup of gypsum deposits, plugging in various parts of the systems, low percentage of SO_2 removal, and difficulty in collecting particulate matter from the exit gas.

In spite of the difficulties encountered, the lime and limestone wet scrubbing processes are flexible and applicable to variable gas flows and sulfur dioxide concentrations. They may well be the first processes applied to dilute smelter gases and could conceivably be on stream within 5 years. The Smelter Control Research Association, Inc. currently is evaluating the application of the limestone scrubber to copper smelter gases at one of the Western smelters.

Reduction of SO_2 to Elemental Sulfur

Reduction of sulfur dioxide to elemental sulfur has been investigated at a number of smelters. The processes investigated were not adopted because they were not economically favorable.

Typical of the reduction processes is the American Smelting and Refining Company's sulfur or brimstone-process, shown in Figure 5. In this process gas containing sulfur dioxide is cooled, cleaned, and reacted with natural gas by combustion at 2200°F. to reduce the

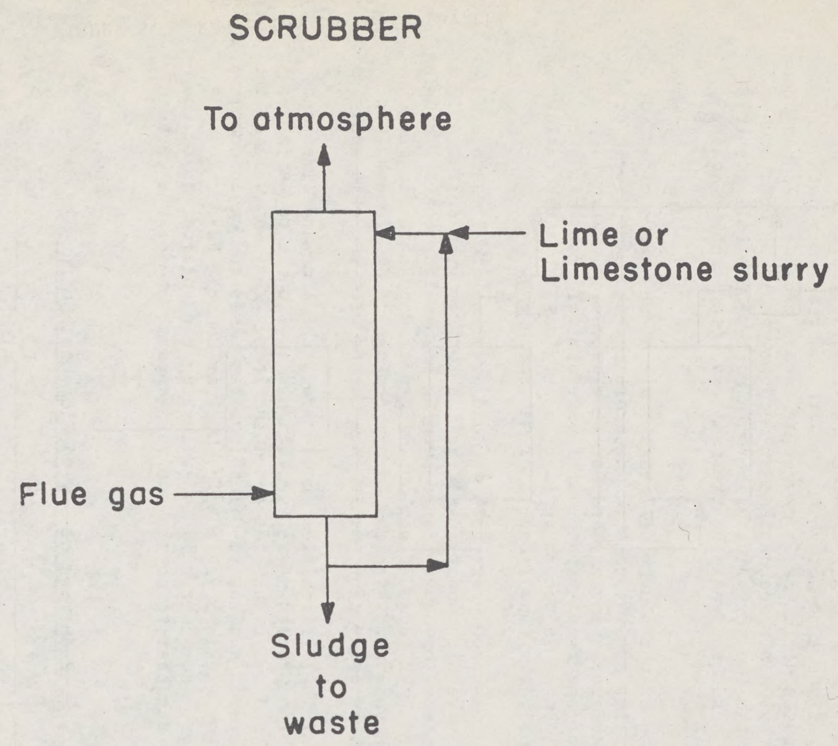

FIGURE 4. - Lime or Limestone Wet-Scrubbing Process (Howden -ICI and Mitsubishi)

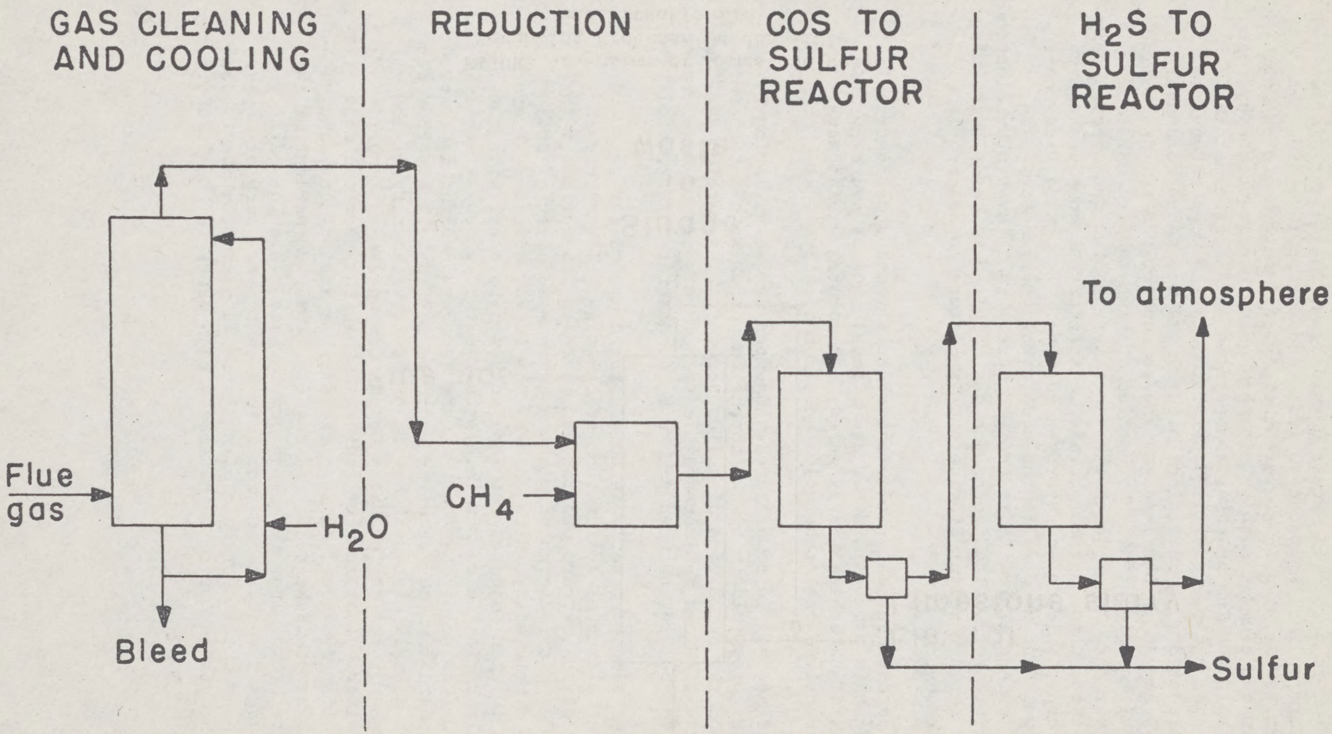

FIGURE 5. - Reduction to Sulfur by the Asarco Process

oxygen content to zero. In excess natural gas, the sulfur dioxide reacts to form sulfur, hydrogen sulfide, and carbonyl sulfide. A bauxite catalyst is used to convert the carbonyl sulfide to sulfur, and an activated alumina catalyst is then used to convert the hydrogen sulfide to sulfur. The process was operated on a semicommercial scale on copper roaster gas (7.25 percent SO_2) and copper converter gas (5.5 percent SO_2). Sufficient natural gas was added to consume the residual oxygen in the feed gas and to convert the sulfur dioxide present to elemental sulfur. Combustion at high temperature took place in a furnace, after which the gases were cooled and successively passed in stages through three catalytic reactors to complete conversion of carbonyl sulfide and hydrogen sulfide. The gases were cooled, and sulfur was condensed following each catalytic reactor. The resulting liquid sulfur mist in the gas stream is recovered by electrostatic precipitators. The process is best applied to gases containing from 5 to 7 percent sulfur dioxide and is claimed to be capable of 95 percent recovery.

The use of natural gas as a reducing agent may pose some restriction for adopting this process. Other reductants, such as hydrogen and carbon monoxide have been investigated, but natural gas appears to be most attractive both technically and economically.

Although the process is complicated and expensive, a variation is being investigated jointly by two copper companies with a test unit having a capacity of 20 tons of sulfur per day. Information available to the Bureau of Mines indicates at least 3 more years of development work is needed before the process can be demonstrated successfully.

The Bureau of Mines currently is developing a method for recovering and producing elemental sulfur from stack gases. The method is referred to as the citrate process and is shown schematically in Figure 6. The gas is scrubbed with an aqueous solution of sodium citrate and citric acid, which absorbs the sulfur dioxide. Hydrogen sulfide gas is then injected into the solution to react with the absorbed sulfur dioxide to form elemental sulfur, which is easily filtered from the solution. Part of the recovered sulfur is reacted with hydrogen to form the required hydrogen sulfide. The method was studied with a small test unit having a gas flow capacity of 350 cubic feet per minute at the Magma Copper Company's San Manuel, Arizona, smelter. Test results indicated that the chemical capability to remove sulfur dioxide from lean streams was satisfactory and that the sulfur could be recovered readily. Over 90 percent of the sulfur was recovered from reverberatory furnace gas. The data available suggest costs to be from 2 to 3 cents per pound of copper smelted with no credit for sale of sulfur. An operating plant based on this method is estimated to be from 4 to 5 years in the future.

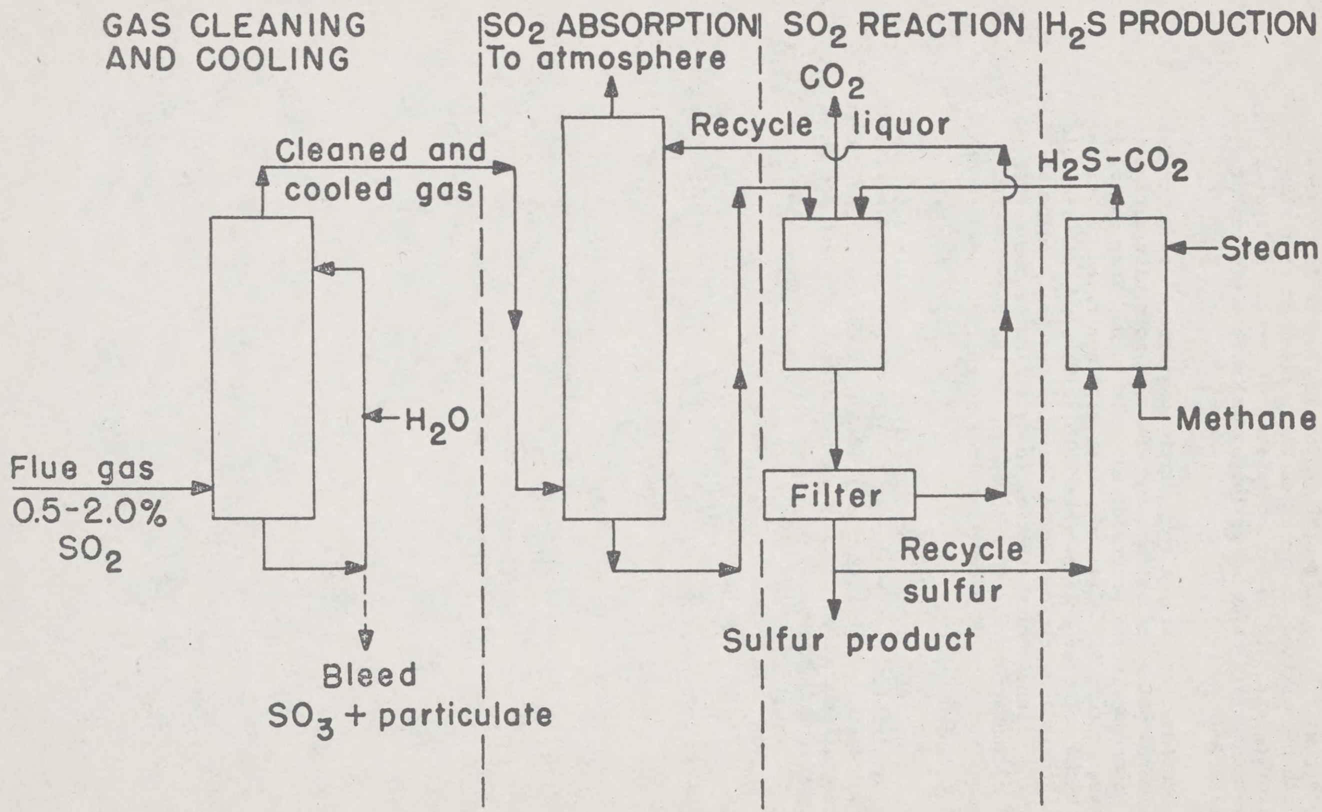

FIGURE 6. - Sodium-Citrate-Citric Acid Process (U. S. Bureau of Mines)

Processes that produce elemental sulfur are desirable because sulfur can be marketed at distances three times greater than can sulfuric acid. If no market exists, sulfur can be stored readily without air or water pollution and with a minimum of land pollution.

Transportation costs are of considerable importance in determining the delivered prices of sulfur, and are even more significant in regard to the delivered prices of sulfuric acid. They could, in some cases, result in delivered prices that are twice the sales price at the point of origin since both sulfur and sulfuric acid are relatively low-priced. Commodities, geographic source of supply, and related transportation costs delineate the market areas for manufacturers. This poses one of the most severe limitations for producing excess sulfur or sulfuric acid at the western copper smelters.

If there is no ready market for the sulfur or sulfuric acid, the economic desirability of producing it will be subordinated to pollution control. The sulfur or acid may be dumped on the market regardless of production costs, a rather dismal prospect for the domestic sulfur industry.

SULFUR PRODUCTS

Compliance to stringent air pollution regulations will affect the domestic copper industry's position as a major world producer because of increased production costs. What degree the increase in cost will be cannot be assessed readily because of the many factors involved. One of these factors is the disposal of products.

As technologies are developed for treating smelter gases to remove sulfur oxides, the byproducts will more than likely be either sulfur, sulfuric acid, concentrated sulfur dioxide, or solid sulfur-bearing compounds having little market value. There are unique or particular situations where the capture of sulfur as acid or other compounds can be advantageous. When the smelter is located where sulfuric acid is required for leaching oxide ore or copper-bearing mine waste, at least some of the sulfur oxides can be transformed to acid and economically consumed. Other smelters are so located that a market for acid exists as a manufacturing intermediate product and, within market saturation, there is reason to produce acid.

Still another situation that may influence adoption of a sulfur emission control process is the conversion of sulfur dioxide to acid bisulfite for treating leach liquors to reduce acid requirements and the amount of iron required for cementing the copper. A study of this approach has been announced by Kennecott Copper Corporation but there are reservations as to the overall effect on recovery in full scale operations. Furthermore, only a limited quantity of the acid bisulfite could be used for this purpose throughout the copper industry.

Under conditions where sulfuric acid or concentrated sulfur dioxide are economically unmarketable and present a disposal problem, removal of the sulfur oxides from the smelter gases as elemental sulfur has certain advantages. Sulfur can be stored readily without air or water pollution and only minor land pollution. If needed at a later time, it can be recovered easily, and shipped without any unusual precautions.

Only through a fortuitous set of circumstances will a smelter operator realize a credit in his ledger for pollution control byproducts. More likely, an additional cost will have to be added for pollution control.

Both capital and operating costs rise rapidly as the percentage recovery of the sulfur increases, with the result that the final increments of sulfur recovery are extremely expensive. Cost of byproduct marketing or waste disposal add to the expense. A balance must be reached for the extent of control between what is required by the public regulatory agencies and what can be accomplished within the economic capabilities of the domestic copper smelting industry without destroying the competitive position of that industry.

APPROACHES TO SOLVING THE PROBLEM

The industry is taking action to achieve an acceptably clean environment, but costs are high and time to achieve the desired end may take longer than demanded by the new environmental standards. Because of the large sums of capital investment required without opportunity for return on investment, both industry and Government have attempted to obtain reasonable estimates of capital costs. Operating costs, too, have been estimated to indicate the potential influence on the price of domestically produced copper.

For industry the Fluor Utah Engineers and Constructors Corporation was engaged in 1970 by the Kennecott Copper Corporation to determine the cost to the copper industry of conformance with the existing and anticipated air quality regulations. The study included 12 of the 14 Western smelters. Both capital costs and incremental costs were estimated for several different methods of controlling smelter emissions. Capital costs estimates ranged from a high of $607 million to a low of $264 million, and incremental costs from 16.6 to 2.8 cents per pound of copper produced. The five methods reported for controlling sulfur dioxide emissions were all considered capable of allowing the smelters to meet the ambient air quality standard with some degree of production curtailment when necessary. Only two of the methods, caustic scrubbing in series with limestone scrubbing and caustic scrubbing with sodium sulfate production, were reported as capable of removing adequate sulfur dioxide to satisfy the 90 percent removal emission standard.

The $607 million capital cost estimate was for installation of acid plants and production curtailment as a method of control. The figure included the cost of a new smelter having a capacity of 2,500 tons per day of copper. The new smelter would offset the loss of copper production during periods of curtailment at the other smelters. This method of control was considered as proven technology, defined as technology developed to the extent that it could be put into operation within 3 years. Incremental costs were estimated at 5.2 cents per pound of copper produced.

The other method considered as proven technology was the replacement of reverberatory furnaces with flash smelting units and installation of acid plants for removing the sulfur dioxide. Capital costs estimated for this technology were $572 million and incremental costs of 2.8 cents per pound of copper produced.

The methods reported as second level technologies, defined as those not yet developed to the point that they could be built in 3 years, were ammonium sulfate production, elemental sulfur via gas concentration and reduction, caustic scrubbing and limestone scrubbing. Estimates were reported for three systems.

Capital costs for limestone scrubbers were the lowest at $204 million. The incremental costs were 3.8 cents per pound of copper produced. Capital costs for caustic scrubbers in series with limestone scrubbers were slightly higher, $275 million and an incremental costs of 5.6 cents per pound of copper. The highest incremental cost reported, 16.6 cents per pound of copper, was for caustic scrubbers and sodium sulfate production. For this system the capital costs were $331 million.

To avoid legal difficulties, Fluor Utah wrote the report on an industrywide basis, and does not reveal optimum action for any particular smelter. The mathematical model that was used, however, took into consideration variables in conditions at each smelter.

Research Triangle Institute estimated for the Environmental Protection Agency that the capital costs for reaching the emission control level would be only $80 million and operating costs about $30 million. The wide variation between these estimates and those of Fluor Utah has given rise to heated controversy.

The Bureau of Mines has insufficient data to make more than a cursory estimate. Based on engineering knowledge and partial equipment cost data, however, it appears that the total capital outlay required will be in the hundreds of million dollar range. Thus, it is indicated that the Fluor Utah figures are reasonable and probably accurate to within 15 percent. With adequate allowance for disposal of sulfur products and the enactment of more stringent standards, the actual capital cost may exceed even the highest estimate. Allowance should also be made for lost production during the period of construction.

It is doubtful that EPA estimates can be compared directly with those of industry. A detailed examination of the methods used by both would be necessary so that adjustments for comparison purposes could be made. Nevertheless, the discrepancy in the two ranges of estimates is unduly wide and suggests the need for an objective evaluation. In light of this situation, the Bureau of Mines intends to study industry's estimates in detail.

Regardless of the exact amount of capital expenditure required, outlay of huge amounts of capital demands careful planning to assure that the control methods selected will be effective and reliable without transforming the air pollution problem to one of land or water degradation.

In addition, a solution that does not lower the world profile of our domestic industry will be reached only if there is tolerance in the time allotted for reducing emissions, particularly for those smelters that cannot readily dispose of sulfuric acid. In the end, the public interests will be best served if allowances are made for the difficulty in bringing technology to a working practice. Both industry and Government whould make a concerted effort as quickly as possible to attain the needed technology, and both should exercise their responsibility to explain to the public the limits of what can be and what is being done to solve this environmental problem within the present state of the art.

Individually, every primary copper producer has implemented a program that will lead to partial if not total compliance to both air quality and sulfur emission standards. These programs vary according to smelter age and location, capability to consume or market acid, sulfur content of the feed, and smelting practice.

Those companies operating old smelters are faced initially with the problem of collecting and channeling their offgases into a flue system where treatment of the gas can be accomplished. This step is essential for compliance to stringent emission standards, and poses costly and time-consuming modifications. Millions of dollars are required to tighten hoods, flues, and other duct work.

For some smelters, both old and relatively new, different charging practices will need development. At some, only installation of new furnaces will give the required high sulfur offgases. Announcements have been publicized for replacement of reverberatory furnaces with flash smelting or electric smelting equipment to produce matte and an offgas rich enough in sulfurous oxides for the production of acid. Modifying the smelting process by this kind of a flow sheet will undoubtedly permit removal of enough of the sulfur dioxide to yield a final stack gas that will meet ambient air quality standards.

Almost every smelter is either planning or already constructing new capacity for making sulfuric acid for reducing emissions from roasting furnaces or convertors. Nearby sources of low-cost limestone will allow some smelters to readily neutralize excess acid for disposal. For others disposal will be costly and may well prohibit acid production as a control measure. Acid production from convertors can be expected to reduce about half of the sulfur dioxide generated in the total smelting operation. This production will be a partial technical solution, but will not be a commercial solution. The cost for erecting acid plants will be greatly expanded by the ancillary expense of installing new water-cooled hoods on the convertors, tightening up or installing new flues and duct work, and providing extensive gas cleaning equipment. For example, one company's report of capital expenditure for a 1,000 ton-per-day acid plant to remove from 50 to 60 percent of the smelter's sulfur dioxide emission is $17 million. Of this amount, almost two-thirds was attributed to gas collection and cleaning equipment. A more striking example is the $220 million which another copper company has estimated for installing acid plants and collection systems at three copper smelters in Arizona.

Even though acid production is a proven technology for removing sulfur dioxide from the richer smelter gases, the installation of acid plants will require considerable time. This time will range from 2 to 3 years for the modern smelter with favorable conditions to upwards of 5 years for old smelters were considerable gas collection and cleaning equipment must be installed. Moreover, the pace for constructing the treatment facilities will be slow if serious curtailment in production is to be avoided.

Some smelters are seeking solution to the problem through development programs that, if successful, will allow production of either liquid sulfur dioxide or elemental sulfur. It is not likely that this technology will be commercially available in less than 5 years and might require 10 years before satisfactory plants are on stream.

Several smelters are monitoring both weather patterns and atmospheric sulfur dioxide concentrations for the area affected by the smelter. Through continuous evaluation of the data the smelter operation can be adjusted to prevent excessive buildup of the contaminant over the area.

Collectively, eight copper producers that account for substantially all of the primary copper production, have established a nonprofit research organization to develop new or improved methods for removing sulfur dioxide and particulate matter from smelter stack gases. The organization, called Smelter Control Research Association, Inc., will conduct research and sponsor investigations to test selected control processes at member plants.

A possible alternative to solving the smelter air pollution problem is to recover copper by methods other than the pyrometallurgical reduction process. Many hydrometallurgy and other chemical processes have been proposed, some have been intensively investigated, and a few have been practiced.

Acid leaching of sulfide ores too low in grade to justify milling costs and oxide minerals that cannot be concentrated is the only hydrometallurgical process that makes a significant contribution to domestic production. The amount of copper recovered by leaching has increased more than three-fold in the last 25 years, but still accounts for less than 15 percent of the primary metal produced.

Except for leaching, the nonsmelting methods for copper have been either too costly to compete against the smelter or lacking in sufficient technology for engineering full-scale plants.

Although posed as an alternate to emission control, nonsmelting pollution-free processes will not emerge for many years as ready substitutes for copper smelting. A strong and continuing research effort is needed to develop the technology, and this must be followed by demonstration on a scale that produces meaningful data for both engineering design and cost evaluation. Matte smelting and converting will continue as the principal process for copper production during the remainder of this century.

APPENDIX

National

Proposed standards were issued by the Environmental Protection Agency on January 25, 1971. After hearings, the final standards were promulgated April 30, 1971, as authorized by Section 4, Public Law 91-604, 84 Stat. 1969. There are two basic standards: Primary, to state how clean the air must be in order for it to be healthful for humans to breathe, and secondary, to state how clean the air must be in order to protect against the known or anticipated effects of air pollution on property, material, climate, economic values, and personal comfort.

Primary - To protect the public health

Ambient air - As sulfur dioxide

a) 80 micrograms per cubic meter, annual arithmetic mean.
b) 365 micrograms per cubic meter, maximum 24-hour concentration not to be exceeded more than once per year.

Secondary - To protect the public welfare

Ambient air - As sulfur dioxide

a) 60 micrograms per cubic meter, annual arithmetic mean.
b) 260 micrograms per cubic meter, maximum 24-hour concentration not to be exceeded more than once per year.
c) 1,300 micrograms per cubic meter, maximum 3-hour concentration not to be exceeded more than once per year.

Arizona

Established by the State Department of Health pursuant to the authority granted by 36-1707, Arizona Revised Statutes, and became effective upon the date of promulgation. Operations not in compliance with the regulations may apply for a provisional permit to continue operating. This permit may be granted if evidence is presented that the operator is diligently pursuing a course of investigation, design and construction that will obtain compliance with the regulations. In any case, full compliance must be met by the year 1973.

Emission - As sulfur - Ten percent of total feed of sulfur to smelter, maximum of 6,500 lbs. per hour.

Ambient air - As sulfur dioxide - ground-level concentration outside the boundaries of the operation.

a) 50 micrograms per cubic meter, maximum annual average.
b) 250 micrograms per cubic meter, maximum 24-hour average.
c) 850 micrograms per cubic meter, maximum 1-hour average.
d) 120 micrograms per cubic meter, maximum any 3 consecutive days.

Michigan

The State has not established any specific standards or regulations regarding sulfur dioxide emissions. Those ambient air standards proposed by EPA probably will become those adopted by the State. No emission standards have been proposed.

Montana

Established by the State Department of Health, pursuant to the Clean Air Act of Montana, Cap. 313, State Legislature, 1967. The effective date is June 30, 1970. For existing operations, full compliance with emission standards must be obtained by June 30, 1973.

Emission - As sulfur - Ten percent of total feed of sulfur to smelter, maximum of 10,000 lbs. per hour, effective June 30, 1973.

Ambient air - As sulfur dioxide - ground level concentration outside the boundaries of the operation.

a) 286 micrograms per cubic meter, maximum 24-hour average.
b) 572 micrograms per cubic meter, maximum 30-minutes per hour, twice in 8 hours.
c) 1,430 micrograms per cubic meter, maximum 10-minutes per hour, twice in 8 hours, total of 60 minutes in 24 hours.
d) 2,860 micrograms per cubic meter, maximum 5 minutes per hour, twice in 8 hours, total of 30 minutes in 24 hours.
e) 5,720 micrograms per cubic meter, maximum 2-1/2 minutes per hour, twice in 8 hours, total of 15 minutes in 24 hours.
f) 5,720 micrograms per cubic meter, maximum at any time.

NOTE: State standards of ppm by volume have been converted to micrograms per cubic meter.

Nevada

Established by the State Board of Health on November 16, 1970, pursuant to Nevada Revised Statutes 445.400 to 445.595 inclusive. The effective date of compliance is December 17, 1970. Existing operations not in compliance with the regulations must submit plans for compliance within 6 months of receipt of instructions from the Air Control Pollution Control Authority to submit such plans. Such compliance plans shall contain specific progress steps that will be taken toward achieving compliance. In any case, full compliance must be attained by December 17, 1973.

Emission - As sulfur - Ten percent of total feed of sulfur to smelter, maximum of 10,000 lbs. per hour, effective December 17, 1973.

Ambient air - No specific standards established.

New Mexico

Established by the New Mexico Health and Social Services Board on January 23, 1970, and amended on June 27, 1970, as regards variances, pursuant to the New Mexico Air Quality Control Act, Chap. 277, Laws of 1967, and amended by Chap. 58, Laws of 1970, and again amended on June 26, 1971. Existing operations were to obtain full compliance by July 1, 1970, unless a variance was obtained from the board. The amended regulations allow operations to apply for a variance, stating their reasons for a stay of action in respect to compliance. Pending a final decision on an application for a variance, a stay of action on compliance is allowed at the discretion of the Director of the Board.

Emission - Separate standards are being considered for power plants, copper smelters, oil and gas refineries, and other sources.

Ambient air - As sulfur dioxide.

a) 57 micrograms per cubic meter, maximum annual arithmetic mean.
b) 286 micrograms per cubic meter, maximum 24-hour average, not to be exceeded more than once in any 100 consecutive days.

NOTE: State standards of ppm have been converted to micrograms per cubic meter.

Tennessee

Established by the State Department of Public Health on June 25, 1969, pursuant to the Tennessee Air Pollution Control Act, Tennessee Code Annoted Section 53-3408, and became effective August 9, 1969. In the case of existing operations which are not in compliance with the regulations, a plan of action that will insure compliance must be filed within 18 months from August 9, 1969. Such plans must show that compliance will be attained before August 9, 1973. Permits for operation pending compliance may be issued for periods of one year or more. Land is classified by usage for purposes of standards to be employed. The applicable standards below are for industrial areas.

Emission - Standards are under study.

Ambient air - As sulfur dioxide - air in general area

a) 572 micrograms per cubic meter, maximum 24-hour average, during 100 consecutive days.
b) 1,430 micrograms per cubic meter, maximum 1-hour average, during 100 consecutive hours.

Texas

Established by the Texas Air Control Board pursuant to the Clean Air Act of Texas, 1967, Art. 4477-5, V.T.C.S., effective January 6, 1968, with provision for full compliance by July 1, 1968. Existing operations that cannot fully comply with the regulations without providing new or additional equipment or facilities, or modifying existing equipment or facilities, may apply for a variance from the regulations pending such provisions as are necessary for full compliance. Land areas are classified by usage for purposes of standards to be met. The applicable standards below are for residential areas.

Emission - No specific standards established.

Ambient air - As sulfur dioxide - 3 to 10 feet from ground level, outside the boundaries of the operation.

a) 572 micrograms per cubic meter, maximum 24-hour average.
b) 1,144 micrograms per cubic meter, maximum 30-minute average, once during any 12 hours.

NOTE: State standards of ppm by volume have been converted to micrograms per cubic meter.

Utah

Regulations in the process of adoption by the Utah State Division of Health.

Emission - Not established.

Ambient air - As sulfur dioxide - at any given point.

a) 57 micrograms per cubic meter, maximum annual average.
b) 286 micrograms per cubic meter, maximum daily average.
c) 1,430 micrograms per cubic meter, maximum 30 minute period, 5 periods per day, 60 periods per calendar month.
d) 2,860 micrograms per cubic meter, maximum 30 minute period, 2 periods per day, 20 periods per calendar month.

NOTE: State standards of ppm by volume have been converted to micrograms per cubic meter.

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Washington

Regulations as established by the Puget Sound Air Pollution Control Agency. They are regional regulations for sulfur dioxide based on regulations issued by the Washington State Air Pollution Control Board, adopted April 17, 1970, effective June 17, 1970, and amended July 8, 1970.

Emission

a) As sulfur dioxide - 5,720,000 micrograms per cubic meter, maximum concentration of flue gases.
b) As sulfur - Ten percent of total feed of sulfur to smelter.

Ambient air - As sulfur dioxide - 10 to 150 feet above ground level, outside boundaries of the operation.

a) 57 micrograms per cubic meter, maximum annual average.
b) 114 micrograms per cubic meter, maximum monthly average.
c) 286 micrograms per cubic meter, maximum 24-hour average.
d) 715 micrograms per cubic meter, maximum 60-minute average, twice in any 7 consecutive days.
e) 1,144 micrograms per cubic meter, maximum 60-minute average.
f) 2,860 micrograms per cubic meter, maximum 5-minute average, once in any 8 consecutive hours.

NOTE: State standards of ppm by volume have been converted to micrograms per cubic meter.

THE IMPACT OF SULFUR OXIDE EMISSION STANDARDS AND THE PROPOSED SULFUR EMISSION TAX ON THE DOMESTIC NONFERROUS SMELTING INDUSTRY

IN

COPPER SMELTING

UNITED STATES DEPARTMENT OF THE INTERIOR

Rogers C. B. Morton, Secretary

BUREAU OF MINES

Elburt F. Osborn, Director

July 1971

THE IMPACT OF SULFUR OXIDE EMISSION STANDARDS AND THE PROPOSED SULFUR EMISSION TAX ON THE DOMESTIC NONFERROUS SMELTING INDUSTRY

THE PROBLEM

Existing State and Federal legislation poses the threat of serious impairment to the nonferrous smelting industry in the United States. Producers of copper, lead, and zinc are being confronted with stringent emission control regulations which are in various stages of becoming law at State and local levels. If proposed sulfur emission tax legislation should be enacted, the problems facing the industry will be compounded.

Air pollution control laws in States where smelters operate require that the States develop implementation plans which must be filed by January 31, 1972. These plans, setting forth procedures whereby all air pollution sources will meet the primary ambient air quality standards recommended by the EPA must be implemented by 1975. In addition, a recommendation made by the EPA that the smelters be required to reduce emissions to 10 percent of the sulfur in the smelter feed, has been made a regulation in Arizona, Montana, Nevada, and the Puget Sound Area.

To comply with these regulations capital investment projected by the copper industry alone would be in excess of $500,000,000. This does not include the costs of the lead and zinc industry. These estimates are based on the use of proven technology for sulfur removal from smelter gases, largely limited to sulfuric acid production. An enormous acid disposal task would be created threatening future enviornmental problems of a dire and unpredictable nature.

Known, but unproven, alternate technologies for removal of sulfur oxides are even more costly. Time and money are required to develop viable processes for reducing sulfur emissions to levels required by the air pollution regulations.

SIGNIFICANCE OF THE INDUSTRY

The importance of the major metals of the nonferrous smelting industry to the United States economy is shown in Table 1. In summary, the copper, lead, and zinc smelters produced 3.2 million tons of metal in 1970, up from 2.3 million tons in 1960. It is anticipated that such growth will continue and that by 1980 smelter production will increase 30 percent to more than 4 million tons. During the decade, 1960-1970, the value of nonferrous smelter output increased from $1 billion to $2.3 billion. Total direct employment in the industry, mine through refinery, totals 58,000 employees with 23,000 men required in the smelting and refining operations.

The growth of the industry, both past and anticipated, is accompanied by numerous problems. Certainly the most pressing problem is disposal of sulfur, an integral part of the ore, without harmful effects on the environment. The quantities of sulfur contained in the smelter feeds are indicative of the magnitude of the problem. In 1960, smelter feeds contained nearly 2 million tons of sulfur; by 1970, this had increased to 2.3 million tons and it is estimated that by 1980, 3.2 million tons of sulfur will enter nonferrous smelters annually in copper, lead, and zinc concentrates. Of the sulfur entering the smelters in 1960, 387,000 tons or 20 percent was recovered as sulfuric acid, in 1970, 600,000 tons or 29 percent of feed sulfur was recovered as acid.

Copper

The United States has been the leading copper-producing country in the world since 1883. Arizona was the leading State in 1970 with 54 percent of total domestic output followed by Utah, New Mexico, Montana, Nevada, and Michigan in ranked order. These six States accounted for 97 percent of the 1.7 million tons of 1970 mine production. Open pit mines supplied 84 percent of mine output and underground mines 16 percent.

Virtually all copper ore was treated at concentrators near the mines. Concentrates were processed at 17 smelters--eight in Arizona and one each in Utah, Michigan, Montana, Nevada, New Mexico, Tennessee, Texas, New Jersey, and Washington. Copper smelting capacity in the United States totaled 9.2 million tons of charge, estimated to represent 1.8 million tons of smelter product. Four companies control nearly 80 percent of the smelter capacity.

Refinery capacity is estimated to be 2.7 million tons of which 88 percent was electrolytic refining capacity and 12 percent fire refining. About 60 percent of the electrolytic refinery capacity

Table 1.--Primary Nonferrous Smelter Operations
(Quantities in thousands of tons and millions of dollars)

	1960	1970	1975 e/	1980 e/
Smelter output, primary-				
Copper	1,134	1,641	1,940	2,250
Lead	385	678	734	793
Zinc	800	878	980	1,090
Total	2,319	3,197	3,654	4,133
Value of smelter output 1/-				
Copper	$727	$1,895	$2,240	$2,600
Lead	92	183	198	213
Zinc	207	269	300	334
Total	$1,026	$2,347	$2,738	$3,147
Sulfur contained in smelter feed e/				
Copper	1,490	1,805	2,035	2,500
Lead	60	101	102	110
Zinc	400	439	490	545
Total	1,950	2,345	2,627	3,155

e/ Estimated by the Bureau of Mines.
1/ Market value of metal - 1970 market prices used for 1975 and 1980.

is accounted for by six plants on the Atlantic Coast in New York, New Jersey, and Maryland. The States of Arizona, Missouri, Montana, Texas, Utah, and Washington each have one electrolytic refinery, which in total accounted for the remaining 40 percent. Fire refined copper is produced in the States of Michigan, New York, New Jersey, New Mexico, and Texas.

In 1970 consumption of refined copper was 2.2 million tons. An additional 0.7 million tons was consumed as scrap in production of alloys, chemicals and other products. The refined consumption was 61 percent by wire mills, 37 percent by brass mills, and 2 percent by others. Scrap copper was consumed principally by smelters to produce refined copper and copper alloy ingots and also by brass mills.

The largest use of copper is in electrical equipment and supplies which accounts for about 1/2 of demand. The manufacture of electric motors, power generators, motor-generator sets, electrical controls and related apparatus requires the use of copper for the best performance. Copper is vital to industrial and military needs in many other use areas such as in construction, transportation, industrial machinery, and ordnance.

The copper industry is considered to be capital intensive with an estimated $3,000 investment required per ton of annual new capacity. On this basis the replacement costs of existing mine-mill-smelter-refinery facilities would be about $4 billion. The smelting sector which must be extensively revamped or replaced to meet the present environmental requirements is estimated to have a replacement cost of $1.2 billion.

Employment in the domestic copper producing industry is about 39,000 distributed between the mine, mill, smelter, and refinery categories as 48, 18, 24, and 10 percent, respectively. There are, of course, many other people who make their livelihood in providing services to the producers and their employees. Also a substantial part of the country's fabricating and manufacturing industry is directly dependent upon a continued supply of copper for their operations.

Table 2 shows the salient components of domestic supply and demand for copper for 1960 and 1970. Also shown are projections for 1975 and 1980. These projections assume that the Federal Ambient Air Quality Standards will be implemented without significant disruptive effect on normal domestic supply patterns.

Table 2.--Copper Supply-Demand Relationships
(Thousand short tons of copper)

	1960	1970	1975 e/	1980 e/
Components of U.S. Supply				
Mine production---------------	1,080	1,720	1,900	2,200
Smelter production, primary--	1,134	1,641	1,940	2,250
Imports:				
Concentrates---------------	22	33		
Blister--------------------	264	224	550	700
Refined--------------------	143	132		
Secondary materials:				
Refined--------------------	291	512	600	700
Other----------------------	579	736	980	1,100
Distribution of U.S. Supply				
Consumption:				
Refined--------------------	1,398	2,084	2,800	3,400
Other----------------------	579	736	980	1,100
Refined exports--------------	434	221	200	150
Ore concentrates, and matte--	11	62	50	50

e/ Estimated by the Bureau of Mines.

Lead

Although displaced by Australia in a few recent years, the United States has traditionally ranked as the world's leading national source of lead. In 1969 U.S. mines and smelters accounted for respectively 509,000 and 639,000 tons of lead (14.4 percent and 17.9 percent of the world's output). Including those that coproduced copper, zinc, silver, and other elements, some 120 domestic mines reported lead production in 1969. For many years, Missouri has been the leading lead producing State followed by Idaho, Utah, Colorado and other States. The domestic lead mining industry is backed by ore reserves estimated to contain 36 million tons of recoverable lead.

Domestically produced lead ores and concentrates, often comingled with similar raw materials imported, notably from Canada, Mexico, Peru, and Australia, are treated in eight smelters; three in Missouri and one each in California, Montana, Idaho, Utah, and Texas. Five of these smelters have access to ancilliary facilities for refining. The two separate lead refineries that treat domestic and imported base bullion are operated in Nebraska and Illinois.

In 1969 the industry consumed 1.39 million tons of new and reclaimed lead. Approximately 42 percent of this went to manufacture of storage batteries, 28 percent various metal products, 20 percent to gasoline additives and other chemicals, and 7 percent to pigments.

Employment in the domestic lead industry totals about 7,000 workers, of which 4,200 are in mines and mills, and 2,800 in lead and lead/zinc smelting and refining plants. The earnings of these workers are estimated to total about $54 million annually. But a far larger employment and value must be added to embrace those segments of the manufacturing and fabricating industry that are directly dependent on lead.

Salient components of the domestic supply and demand for lead in 1960 and 1970, together with projections for 1975 and 1980 are given in Table 3.

Zinc

The U.S. supply of zinc consists of recoverable domestic mine production, secondary slab zinc and secondary zinc in alloys reclaimed from scrap, the zinc in imported concentrates, imports of zinc metal, zinc in imported zinc compounds, and industry and Government stocks. Of the total 1970 supply domestic mine production furnished 30.4 percent and zinc in imported concentrates 29.9 percent. This mine production and the imported concentrates supplied the raw material feed for four electrolytic refineries and eight smelters.

Table 3. Lead Supply-Demand Relationships
(Thousand short tons, lead)

	1960	1970	1975 e/	1980 e/
Components of U.S. supply:				
Mine production	247	571	600	650
Smelter production, primary	385	678	730	800
Imports:				
Ore and concentrate	155	112	120	130
Metal forms	206	251	270	300
Secondary materials	470	597	650	750
Distribution of U.S. supply:				
Consumption:	1020	1360	1630	1820
Exports, all forms, except scrap	2	8	10	10

e/ Estimated by the Bureau of Mines.

Employment in the zinc industry for 1970 was about 11,600 distributed as follows: Mine and mill 4,600, smelters and electrolytic refineries 7,000. The influence of the zinc industry extends to other industrial activities and their work forces, for example: die casting plants, galvanizing operations, and brass mills which depend upon zinc for their products.

Since 1953 the zinc smelters and electrolytic refineries have been dependent on foreign concentrates for more than 55 percent of their zinc supply. Companies operating the smelters and refineries in 1970 were faced with higher costs for concentrates and pressures for a lower zinc price because of the slackening demand. Early in 1971 three companies announced they would close their plants by mid-year because of the cost-price squeeze and uneconomical operations. Four plants were involved accounting for 257,500 tons of annual slab zinc capacity thus reducing the U.S. total capacity from 1,251,000 tons to 993,500 tons.

Because smelting and electrolytic refining of zinc are reportedly marginal operations, any increase in processing cost would be passed back to the supplier of concentrates as a smelting charge. As a result owners of foreign concentrates would be likely to ship their concentrates to other foreign plants and domestic custom shippers would either close their mines or ship their concentrates to foreign processors. With the rising costs of concentrates it appears the United States must obtain an increasing amount of zinc from imports.

The estimated projections for 1975 and 1980 in Table 4 assume a decline in zinc smelter and electrolytic refining capacity to 700,000 tons at five of the twelve plants that operated in 1970.

Table 4.--Zinc Supply-Demand Relationship
(Thousand short tons of zinc)

	1960	1970	1975 e/	1980 e/
Components of U.S. Supply				
Mine production--------------	435	534	400	500
Smelter production, primary--	800	878	980	1,090
Imports:				
Concentrates---------------	457	526	200	100
Zinc metal-----------------	121	273	800	1,000
Compounds------------------	12	25	30	30
Secondary:				
Refined zinc---------------	69	77	60	50
Alloys and other-----------	198	323	360	400
Government release-----------	5	---	---	---
Distribution of U.S. Supply				
Consumption:				
Metal----------------------	1,100	1,573	1,750	1,960
Compounds------------------	120	180	200	220
Exports:				
Metal----------------------	75	---	---	---
Compounds------------------	2	5	---	---

e/ Estimated by the Bureau of Mines.

COST OF COMPLIANCE

A study of "the Impact of Air Pollution Abatement on the Copper Industry" by Fluor Corporation shows that sulfur removal with present technology would require $607 million of capital expenditures by the copper industry. In addition to the capital costs of the facilities increased annual operating costs would range from $50 to $75 million. Even with this expenditure of funds the report claims that the industry might not be able to meet the 90 percent emission standards already imposed by some states.

The $607 million capital cost estimate was for installation of acid plants and production curtailment as a method of control. The figure included the cost of a new smelter having a capacity of 2,500 tons per day of copper. The new smelter would offset the loss of copper production during periods of curtailment at the other smelters. This method of control was considered as proven technology, defined as technology developed to the extent that it could be put into operation within 3 years. Incremental costs were estimated at 5.2 cents per pound of copper produced.

Imposition of a sulfur emission tax has been estimated as increasing the incremental cost of copper by another 4.3 cents per pound.

The impact of such costs on the domestic industry can be illustrated by applying them to a company producing 240,000 tons of copper annually. An increased cost of 9.5 cents per pound of copper would cost the company $46 million, a major portion of its net income for the year.

Copper, lead, and zinc are internationally traded commodities and domestic production has to compete with foreign production on a cost, service, and reliability basis. Domestic and foreign production are in equilibrium at present. The additional costs incurred by domestic smelters in sulfur emission control will be difficult to pass on to customers because of competition from foreign smelters. To the extent that customers are willing to pay a premium for domestic supply sources for security or service, the increased costs can be passed on to customers. It is impossible to estimate the amount of this premium at present, but it is probably limited.

Assuming that most of the cost increase will have to be absorbed by the producers, they will continue to produce as long as revenue from sales cover the capital and operating costs of the sulfur control equipment plus the present operating costs.

Analysis of aggregate data for primary copper smelters indicates that on an industry average a cost increase of 5 cents per pound can be absorbed in the short run. It is not possible to predict what percentage of the industry could absorb the increased costs and generate enough cash flow to reinvest in capital and remain profitable in the long run.

Control costs of much more than 5 cents per pound could result in shutdown of many of the smelters, as revenue would not cover operating costs.

If some of the smelters close, concentrates would initially be shipped to smelters with excess capacity, probably outside the United States. Eventually, new smelter capacity probably will be built in Canada and Mexico in order to keep transportation charges at a minimum.

Transportation costs for U.S. produced concentrates shipped to smelters outside the United States would put U.S. mines at a cost disadvantage in the world market. Marginally profitable mines would shutdown as capital equipment wears out. Low cost mines would continue production through scheduled useful life to the extent that they can absorb added transportation costs. Exploration efforts would halt and the opening of new mines would cease, as the increased costs vastly reduce if not eliminate the probability of discovering profitable ore bodies in this country.

The impact on the lead and zinc industries is similar to that of the copper industry, except that the zinc refineries may phase out because of additional costs burden. The tight economic situation relating to lead and zinc production already has resulted in closure of several zinc smelters.

In addition to the stifling impact on the nonferrous industry, the implementation of present and proposed standards on sulfur emission controls will have a profound effect on supply-demand situation for sulfur.

ECONOMIC IMPACT

For this study, it is assumed that if the proposed regulations were to be enforced fully and effectively, then in the long run all the copper, lead and zinc smelters and the zinc refineries, which also produce substantial SO_2 would have to be closed down and abandoned entirely. The probable economic impacts on the American economy are likely as follows:

1.	Direct loss of smelter employment.	17,500 jobs
2.	Direct loss of smelter and related industry employment	58,200 jobs
3.	Direct loss of total payroll due to No. 1	$138.6 million
4.	Direct loss of total income due to No. 2	$413.5 million
5.	Direct reduction in value of output shipments in these industries	$1,796.1 million
6.	Direct and indirect losses of value of total output throughout the economy--the interindustry output multiplier effect	$4,567.1 million
7.	The reduction of value due to the abandonment of otherwise useful capital assets in these industries	$617.5 million
8.	The estimate of decline of normal profits in these industries that would have earned otherwise	$179.5 million
9.	The net adverse effects on the U. S. balance of payments	$2,041 million
10.	The losses of State and local taxes	
	State personal income taxes	$2.8 million
	State corporate income taxes	$38.8 million
	Local property taxes	$14.8 million
	Sub-total	$56.4 million
11.	The losses of Federal income taxes	
	Corporate income taxes	$189.5 million
	Personal income taxes	$20.8 million
	Sub-total	$210.3 million

It is further assumed that if all the copper, lead and zinc smelters and all the zinc refineries were to be closed down entirely in one year, then the total economic impact as losses to the economy in that particular one year would be $7,467.8 millions (i.e. the sum of items 4, 6, 8, 9, 10, and 11). For all the subsequent years afterwards, the economic impact would be only the total value of imports of the U.S. economy needed copper, lead and zinc metals. If the U.S. economy should be importing on the scale of 1969, the net adverse effect on the U.S. balance of payments would be $2,194 millions per year for importing the necessary nonferrous metals.

CONCLUSIONS AND RECOMMENDATIONS

It is possible to develop a rationale that the attainment of prescribed clean air standards is for the general welfare of the country and that the costs incurred by industry to meet the standards should be borne by the Federal Government as a part of their responsibility for maintaining the general welfare.

Another possible course of action is to defer the implementation of the Federal Clean Air Act until several actions are taken. More should be known about the costs of conforming and the impact this would have on industry. Research to develop more economical control systems should be started. More has to be known about the impact of SO_2 emissions on public health before an accurate determination of the trade-offs between the benefits of lower sulfur emissions and the costs to industry can be accurately assessed. Federal standards should be controlling.

The possible loss of a large segment of the nonferrous mining and smelting industry is a very high price to pay for possible health benefits which have not been assessed.

Government assumption of the costs of conforming to the standards would become a perennial political problem, as the funds involved would be considered by some influential groups to be subsidies.

Given our present lack of knowledge of the adverse affects and economic means of control; action on implementation should be deferred, and vigorous action taken to assess public health impact and more economic means of control.

BUREAU OF MINES ACCOMPLISHMENTS IN RECYCLING SOLID WASTES

Urban Refuse

The Bureau of Mines has developed a procedure for recovering iron and steel, aluminum, copper, zinc, glass, and other products from incinerated refuse, using techniques similar to those for separating minerals and metals from their ores. During the past 18 months the process has been demonstrated on a pilot scale in a Bureau-designed plant with a capacity of one-half ton per hour of municipal incinerator residues. Each ton of residue yields over 600 pounds of ferrous products, almost 80 pounds of nonferrous metals, 550 pounds of colorless glass, and 400 pounds of colored glass. These products have a value of almost $16 per ton of incinerator residue. Operating costs including capital and amortization over 20 years, for a commercial-size plant, are about $1.80 per ton of residue. A second pilot plant for separating and recovering metals, glass, paper, and plastics from raw, unburned refuse on a continuous basis is under construction and will be in full operation within three months.

Methods to treat the organic portions of refuse by pyrolysis (destructive distillation in the absence of air) or, alternatively, by hydrogenation to produce marketable oils and gas have been proven on a small pilot scale. Hydrogenation tests have shown that one ton of refuse will produce 2 barrels of low sulfur oil. Even higher yields can be obtained from animal manures. The pyrolysis method is also adaptable to plastics, sawdust, sewage sludge and used tires. One ton of scrap tires yields 140 gallons of oil and 1500 cubic feet of high quality fuel gas. A major tire producer has tested the process on an industrial scale.

Laboratory and large-scale studies on refining, and reusing the recovered iron and steel, nonferrous metals, waste glass, and plastics are underway. High-quality structural blocks and mineral insulating wool have been produced from the waste glass.

What Needs To Be Done

1. The design and construction of commercial-size plants to demonstrate the incinerator residue process in order to convince private and municipal bodies of economic practicality.

2. Pilot-scale demonstration of a parallel process for recovering resources from raw refuse.

3. Continued improvement and development of the Bureau's pyrolysis and hydrogenation techniques for obtaining oil and gas from organic wastes.

4. Large-scale tests on the ferrous, nonferrous, and glass products obtained from refuse to demonstrate economics and marketability.

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Junk Autos, Railroad Boxcars, and Other Large Scrap
Current research efforts are concentrated on improving the technology of upgrading automobile and other ferrous scrap so that traditional markets may be maintained and new ones developed. Emphasis is being placed on improved dismantling procedures for junk cars, operation of a smokeless junk car incinerator, and more efficient recovery of high-value metals such as copper, from junk cars and bulk-appliance scrap. Studies are also underway on recovery of nonferrous metals from junk car shredding operations and on utilization of auto scrap for making pig iron.

The Bureau's junk car dismantling studies provided the first reliable information on composition, economic value, and practical dismantling procedures for scrap automobiles. The junk car incinerator has received wide acceptance by scrap processors, and over a dozen commercial units, designed after the Bureau model, are under construction. The prototype facility, which allows smokeless burning of scrap cars, was built at a cost of only $22,000. In cooperation with a manufacturer of shredding equipment the Bureau is designing a large smokeless incinerator which will burn out the wood linings of boxcars at the rate of one every two hours, or the combustible materials in junk cars at the rate of 20 units per hour.

The Bureau also has recently developed a low-cost air separator which will allow scrap processors to recover the nonferrous metals presently lost in junk car shredding operations. The device which was constructed at a cost of about $2000 can process 16 tons of the shredder reject material per hour. Each ton of material contains $55 worth of aluminum, zinc, lead, and copper which, for the most part, are currently being wasted.

What Needs To Be Done

Demonstration of a model scrap processing yard incorporating the latest processing methods developed by the Bureau and others. The model yard would demonstrate the techniques needed to take a scrap car through its entire cycle, from obsolescence to marketable products. Attention will also be directed to greater utilization of bulk-appliance scrap.

Mining and Mineral Processing Wastes

This program is directed toward the stabilization and utilization of the more than 23 billion tons of mining and mineral wastes accumulated across the country. Nearly 7000 square miles of land have already been despoiled by mineral and fossil fuel mining and many unsightly waste piles are a source of air and water pollution. Bureau research has shown that commercially competitive structural materials can be produced from a variety of mineral wastes. Copper mill and gold mine tailings have been used to make building bricks at costs that are competitive with those commercially produced from conventional raw materials. Other studies include recovery of residual vanadium and uranium values from uranium mill tailings and of uranium from solutions used in extraction of copper from its ores. Uses are being investigated for waste gypsum of the phosphate industry, slag from phosphorus production, iron from mill scale, and wall tile from asbestos and other mining industry wastes. Other potential uses exist in backfilling old mines and as railroad and highway road ballast.

Excellent progress has been made in the development of low-cost methods to stabilize fine tailings. These accumulated mineral waste piles and those currently being generated are so large that stabilization is the only practical means of minimizing air and water pollution problems associated therewith. Several possibilities exist for stabilization of fine wastes, which are the main sources of air and water pollution. These include physical, chemical, and vegetative stabilization, and their combinations. A variety of chemicals can be used to bond particles of fine mineral waste into a relatively inert mass. The most promising method of producing an esthetically appealing site is by vegetative stabilization. Numerous species of plants can germinate, grow, and reseed in waste materials after simple preparation methods which make them able to support plant life.

What Needs To Be Done

1. Large scale efforts are urgently needed to develop and prove out low-cost stabilization methods to encourage private industry in their own efforts to deal with the mineral wastes which have accumulated in the past 30 years.

2. Pilot-plant tests are required for Bureau-developed methods of utilizing mineral wastes for construction materials. The technology and economics must be demonstrated on a significant scale.

Industrial Wastes

We have been working on certain aspects of industrial waste products for many years. These include: (1) treatment of metal coating and plating wastes to recover the residual copper, nickel, chromium and zinc with concurrent elimination of the hazardous cyanide and acid pollutants from the waste solution; (2) identification, recovery and reuse of solid wastes issuing as flue dusts from steelmaking operations; (3) recovery and recycle of precious metals from scrap electronic equipment and parts; (4) conversion of waste gypsum into wallboard, (5) development of methods to treat and reuse alloy chips, turnings, and fines which become contaminated during machining and fabrication; and (6) recovery of sulfur dioxide as elemental sulfur from gaseous emissions of smelters and power plants.

What Needs To Be Done

1. Solid wastes of industrial origin comprise a category so diverse and widespread that a massive program of research on identification, quantities, recovery techniques, and utilization is urgently needed.

2. Methods must be developed to combine types of low-value wastes to produce inert materials which can be disposed of safely.

FACT SHEET
Edmonston (Md.) Solid Waste Recycling Project
Bureau of Mines
Department of the Interior

An important part of the solid waste utilization research carried on by the Bureau of Mines is to develop methods and processes for recycling mineral materials present in municipal incinerator residues. Technologists from the Bureau's College Park (Md.) Metallurgy Research Center operate a pilot plant at Edmonston, Maryland, where they have separated ferrous metals, nonferrous metals, and glass from incinerator residues. The following facts are pertinent to the research underway at the Edmonston pilot plant.

xxx - 100 pounds of typical municipal refuse contains: 55 pounds of paper and cardboard; 14 pounds of garbage; 9 pounds of metal; 9 pounds of glass; 5 pounds of leaves, grass, hedge clippings and tree prunings; 4 pounds of scrap wood; 1 pound of plastics; and 3 pounds of unclassified material.

xxx - Municipal refuse generated in the U.S. in 1969 totaled more than 250 million tons, or the equivalent of more than 5 pounds daily for every man, woman, and child.

xxx - Only 190 million tons of municipal refuse was regularly collected by public agencies and private firms. The remainder (60 million tons) was abandoned, dumped at the point of origin, or hauled to uncontrolled disposal sites.

xxx - The volume of municipal refuse accumulating in the U.S. in a single year would cover an area half the size of the State of Connecticut (1,700 sq. mi.) with a layer of refuse 1 foot deep. This refuse contains some 11 million tons of iron and steel, 15 million tons of glass, and over a million tons of aluminum, zinc, lead, tin, and copper.

xxx - Collecting and disposing of refuse costs cities an average of $23 per ton ($18. for collection and $5. for disposal). New York City, at a cost of $26 per ton, spends half a million dollars each day to collect and dispose of solid waste. Total U. S. bill runs about $6 billion annually.

xxx - Most municipal refuse is disposed of by dumping, land-fill, or incineration. About 25 million tons of municipal refuse is burned annually in more than 300 municipal incinerators. These incinerators generate more than 5 million tons of residues, which are then buried.

xxx - An average ton of incinerator residue contains $15.76 worth of mineral values, at current prices:

Product	Value	Quantity/ton of residue, pounds	Value/ton of residue, dollars
Ferrous metals	$10/ton	610	3.05
Aluminum	$0.12/pound	32	3.84
Copper-zinc	$0.19/pound	24	4.56
Colorless glass	$12/ton	552	3.31
Colored glass	$5/ton	398	1.00
		Total	$15.76

xxx - The Edmonston (Md.) pilot plant of the Interior Department's Bureau of Mines has shown that valuable minerals in incinerator residues can be reclaimed in a form suitable for recycling at an average cost of about $3 per ton of residue processed. This would return to cities more than $12 for each ton of incinerator residue processed, to help offset collection costs.

xxx - The Bureau plant uses conventional, off-the-shelf, mineral-engineering equipment to separate mineral values from incinerator residues. The process consists of a series of shredding, screening, grinding, and magnetic separation procedures.

xxx - The Edmonston plant processes incinerator residues at a rate of 1/2 ton per hour -- 4 tons in an 8-hour day or 12 tons in a 24-hour day. Bureau of Mines estimates of operating costs for commercial-size plants indicate economy with increasing size:

Capacity, tons/day	Operating time, hours/day	Operating costs, dollars/ton of dry residue
250	8	4.06
400	8	3.28
670	24	2.32
1,000	24	1.80

xxx - A plant processing 1,000 tons of incinerator residue per day could be expected to reclaim each day enough ferrous metal to make all the iron and steel parts for more than 225 4-door sedans.

xxx - About 36 billion bottles are discarded each year in the U.S. as solid waste. Each American discards a glass bottle on the average of about one every two days. The average returnable beer bottle used to make 31 round trips from the brewery, to the consumer, and back to the brewery. The average is now 19 trips. In some cities, it is only 4. People are discriminating less between returnable and non-returnable bottles.

xxx - Glass reclaimed from incinerator residue can be used in making new glass, or for such salable products as building bricks, mineral wool for insulation, and road surfacing (when ground and mixed with asphalt).

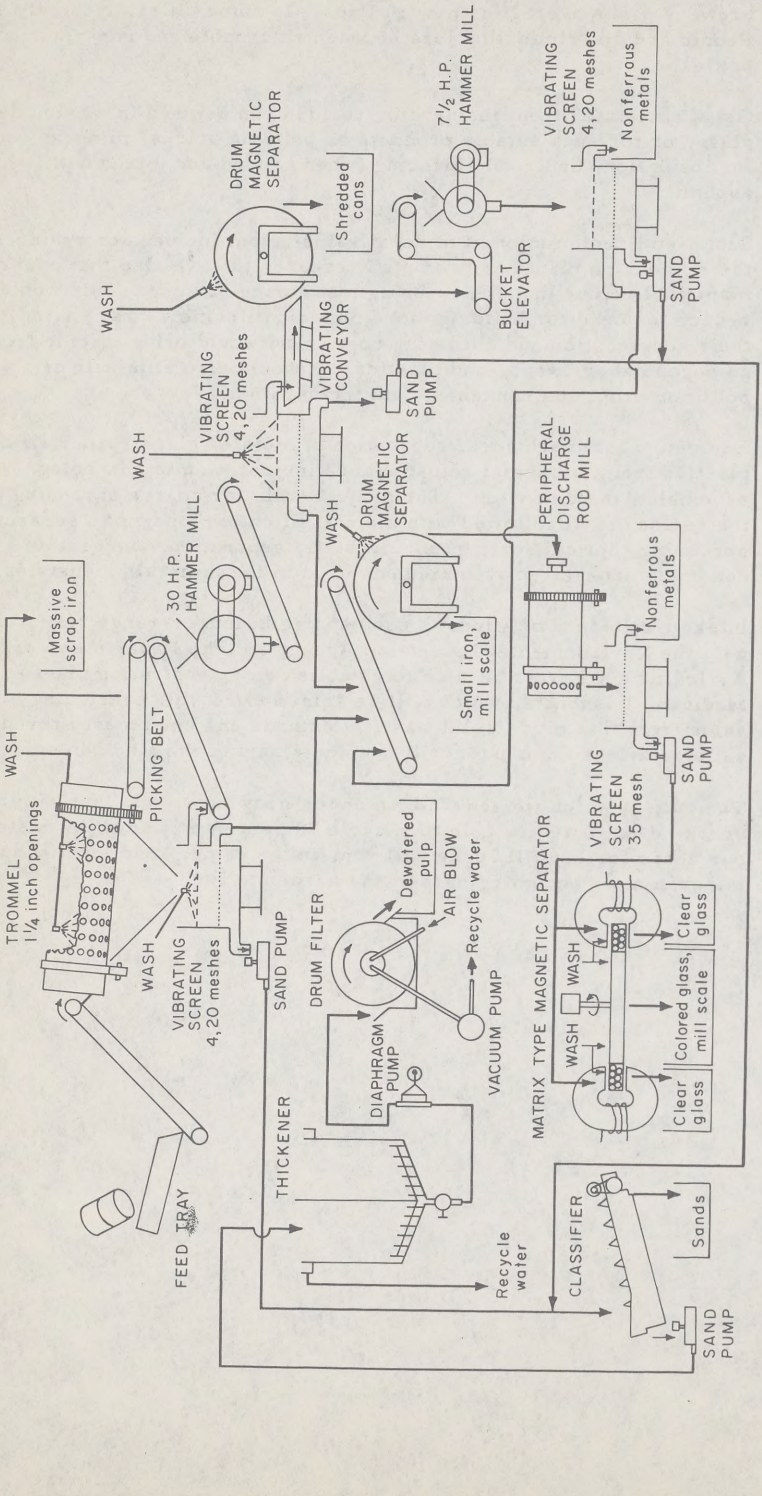
xxx - Successful reclamation of mineral values from incinerator residues at the Edmonston plant has prompted research to save also that part of municipal refuse that is now being lost during burning. This would reduce the need for building more municipal incinerators, saving their construction and operating costs, and would bring income from salvaged paper, wood, and plastics. It would also eliminate air pollution problems connected with incineration.

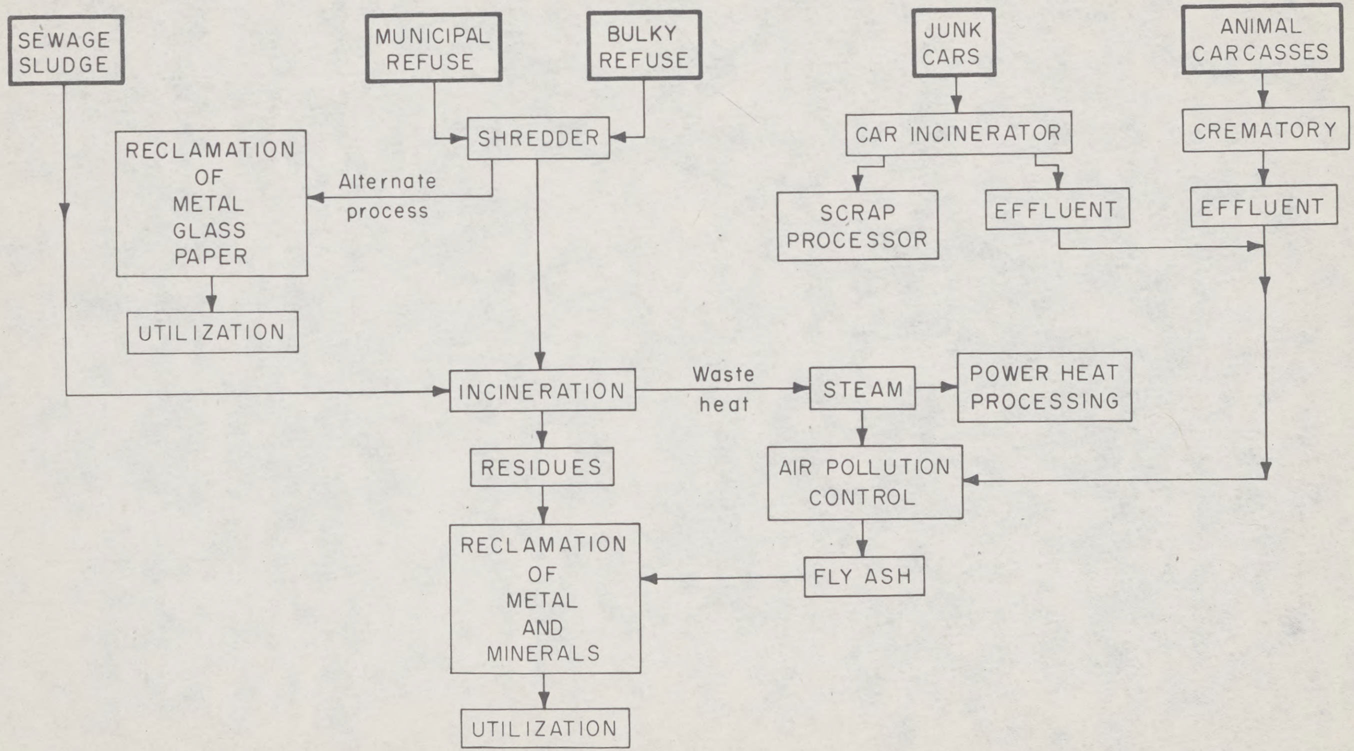
xxx - Equipment for mechanical separation of metals, glass, paper, and plastics from municipal refuse before incineration is now being assembled at Edmonston. The project calls for coarse shredding of the refuse, to be followed with air classification, magnetic separation, screening, optical sorting, electrostatic separation, and gravity concentration--all proven methods used in the minerals industries.

xxx - Interior's Bureau of Mines is cooperating in longer-range research with the Environmental Protection Agency and the Department of Agriculture's Forest Service to establish a demonstration plant at Madison, Wisconsin, which will reclaim and recycle everything of value from that city's solid waste. Methods and equipment proven satisfactory at Edmonston will become a part of the Madison system.

xxx - The rate at which we generate refuse is growing so fast that within 20 years, even if we are able to recycle 70 percent of our solid wastes our needs for landfill space will remain the same. And landfill space is, even now, becoming harder and harder to find.

xxx


FEED TRAY
TROMMEL 1¼ inch openings
WASH
PICKING BELT
Massive scrap iron
30 H.P. HAMMER MILL
WASH
VIBRATING SCREEN 4,20 meshes
SAND PUMP
DRUM FILTER
Dewatered pulp
AIR BLOW
Recycle water
VACUUM PUMP
DIAPHRAGM PUMP
THICKENER
Recycle water
WASH
VIBRATING SCREEN 4,20 meshes
VIBRATING CONVEYOR
SAND PUMP
WASH
DRUM MAGNETIC SEPARATOR
Shredded cans
BUCKET ELEVATOR
7½ H.P. HAMMER MILL
VIBRATING SCREEN 4,20 meshes
Nonferrous metals
SAND PUMP
WASH
DRUM MAGNETIC SEPARATOR
Small iron, mill scale
PERIPHERAL DISCHARGE ROD MILL
Nonferrous metals
VIBRATING SCREEN 35 mesh
SAND PUMP
MATRIX TYPE MAGNETIC SEPARATOR
WASH
WASH
Clear glass
Colored glass, mill scale
Clear glass
CLASSIFIER
Sands
SAND PUMP



ENVIRONMENTAL WASTE MANAGEMENT SYSTEM
Model Municipal Incineration and Reclamation Complex

ECONOMICS OF RECYCLING METALS AND MINERALS FROM URBAN REFUSE

by

P. M. Sullivan[1] and M. H. Stanczyk[2]

ABSTRACT

A physical beneficiation flowsheet was designed by the Bureau of Mines for reclaiming and recycling metal and mineral values contained in municipal incinerator residues, and a continuous processing plant was installed. Residue samples collected from incinerators located in various parts of the country were processed at a rate of 1/2 ton per hour. Continuous screening, shredding, grinding, magnetic separation, and gravity concentration techniques were applied to produce metallic iron concentrates, clean nonferrous metal composites, clean fine glass fractions, and fine carbonaceous ash tailings.

Research to develop systems for refining and upgrading the reclaimed metals and glass into marketable products is also underway. From the engineering data developed in the continuous processing plant, evaluations of the capital and operating costs for plants with capacities of [illegible], and 1,000 tons of dry incinerator residue per day were made.

Research on a pilot-scale system to separate and recover the metals, minerals, glass, paper, and plastics from raw, unburned refuse is currently underway, as well as [illegible] to separate the [illegible] into organic and inorganic fractions.

INTRODUCTION

With the passage of the Solid Waste Disposal Act of 1965, the Bureau of Mines was given [illegible] and expanded its efforts in separating, recovering, and recycling [illegible] from a variety of wastes, minerals, and [illegible] wastes. The program being carried out at the Bureau's College Park, Md., Metallurgy Research Center is aimed at eliminating the current waste of valuable resources in urban refuse by developing low-cost methods for reclaiming and recycling the metal and mineral values contained in municipal incinerator residues and raw refuse.

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ECONOMICS OF RECYCLING METALS AND MINERALS FROM URBAN REFUSE

by

P. M. Sullivan[1] and M. H. Stanczyk[2]

ABSTRACT

A physical beneficiation flowsheet was designed by the Bureau of Mines for reclaiming and recycling metal and mineral values contained in municipal incinerator residues, and a continuous processing plant was installed. Residue samples collected from incinerators located in various parts of the country were processed at a rate of 1/2 ton per hour. Continuous screening, shredding, grinding, magnetic separation, and gravity concentration techniques were applied to produce metallic iron concentrates, clean nonferrous metal composites, clean fine glass fractions, and fine carbonaceous ash tailings.

Research to develop systems for refining and upgrading the reclaimed metals and glass into marketable products is also underway. From the engineering data developed in the continuous processing plant, evaluations of the capital and operating costs for plants with capacities of 250, 400, 670, and 1,000 tons of dry incinerator residues per day were made.

Research on a parallel system to separate and recover the metals, minerals, glass, paper, and plastics from raw, unburned refuse is currently underway, as are studies on the use of air classification to separate the refuse into organic and inorganic fractions.

INTRODUCTION

With the passage of the Solid Waste Disposal Act of 1965, the Bureau of Mines was able to accelerate and expand its efforts in separating, recovering, and recycling the values contained in a variety of metal-, mineral-, and energy-laden solid wastes. The program being carried out at the Bureau's College Park (Md.) Metallurgy Research Center is aimed at eliminating the current waste of valuable resources in urban refuse by developing low-cost methods for reclaiming and recycling the metal and mineral values contained in municipal incinerator residues and raw refuse.

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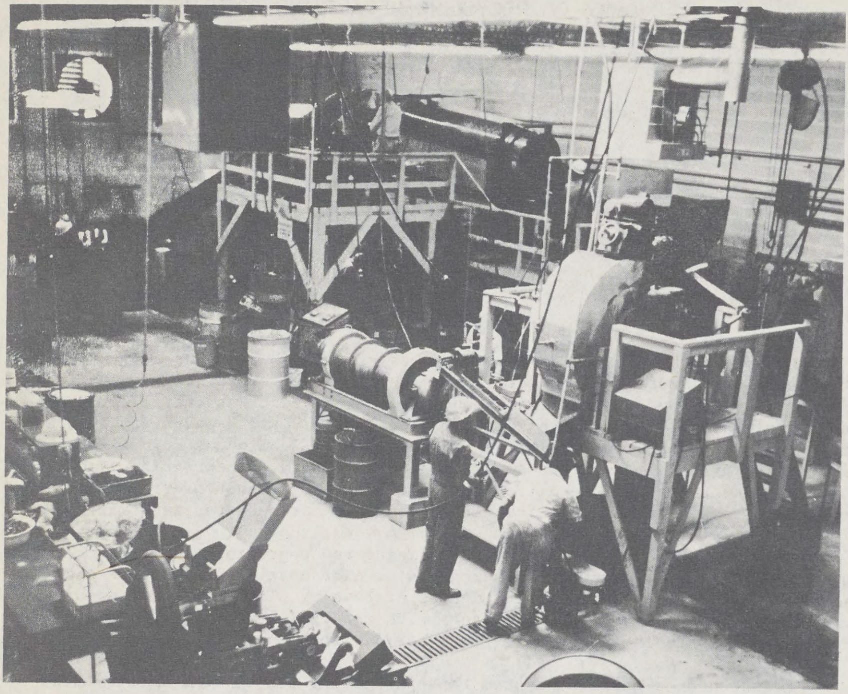

FIGURE 1. - Bureau of Mines Continuous Residue Processing Plant.

The Bureau's early research established the first reliable methods for sampling municipal incinerator residues and characterizing these wet, complex mixtures of metals and minerals. The work (2-3)[3] revealed that metals and glass account for approximately 75 weight-percent of the residues, a proportion that varied surprisingly little from sample to sample, considering the heterogeneous character of residues.

After the general composition of residues had been established, research was focused on developing wet mechanical methods for recovering and separating the residues into fractions that, if necessary, could be further treated to produce products suitable for recycling. Relying exclusively on existing mineral engineering technology, various combinations of mineral beneficiation techniques were investigated. The most promising procedures which evolved

[3]Underlined numbers in parentheses refer to items in the list of references preceding the appendix.

from this research (4-6) were incorporated into the continuous mechanical beneficiation plant shown in figure 1. The plant, designed to process 1,000 pounds of incinerator residues per hour, was constructed for the purpose of developing engineering data to permit design of plants with capacities of 250 to 1,000 tons of residues per day, and evaluation of the capital and operating costs. This report describes the process flowsheet, the results of continuous processing, tests, and cost estimates for larger plants.

THE FLOWSHEET

Incinerator residues are a soaking-wet complex of metals, glass, slag, charred and unburned paper, and ash containing various mineral oxides. The moisture content of residues ranges from about 19 to 47 percent and is primarily dependent on the degree of burnout and the type of quenching used at each incinerator. The degree of burnout at an incinerator is largely influenced by such factors as the moisture content of the incoming refuse, the operating temperature, the capacity at which the furnaces must operate, and the type and state of repair of the furnaces. It should be noted that the process flowsheet incorporated into the continuous processing plant was designed on the basis that the residues would contain a minimum of unburned paper, rags, and organic matter.

Residue samples were collected in tared 30-gallon drums according to procedures developed earlier (3). These were brought back to the laboratory and weighed. A continuous feeding system was simulated by dumping the wet residues on a large metal apron and raking the material to a feed conveyor at a predetermined rate.

Figure 2 depicts the present process flowsheet incorporated in the continuous processing plant. This flowsheet is presented in greater detail in the appendix. The first processing step, after the feeding arrangement, consists of screening in a 3-foot-diameter by 10-foot-long punched plate trommel screen having 1-1/4-inch holes. The trommel screen is fitted with internal lifters to achieve a tumbling action. During screening the residues are sprayed continuously with water. The material scalped off by the trommel is composed primarily of cans, wire, large iron, and some large pieces of nonferrous metal, paper, glass, and some other nonmetals. The minus 1-1/4-inch material is screened and washed on a 30-inch-diameter circular vibrating screen fitted with both 4- and 20-mesh screens. The plus 4-mesh material consists principally of bottle caps, nails, glass, nonferrous metals, and other nonmetals. The minus 4- plus 20-mesh fraction contains glass, other nonmetals, mill scale, fine iron, and nonferrous metals. The minus 20-mesh material is composed principally of carbon, dirt, some fine glass, other nonmetals, and metal oxides.

All of the plus 1-1/4-inch material except the more massive pieces of iron is blended with the minus 1-1/4-inch plus 4-mesh fraction. This composite from the primary screening operation is then shredded in a 30-hp hammermill having 32 swing hammers rotating at a peripheral speed of about 8,500 fpm. The hammermill is fitted with discharge grate bars having 4- by 4-inch openings. The minus 4- plus 20-mesh fraction from screening is joined with the shredded material, and the combined product is transferred to a secondary

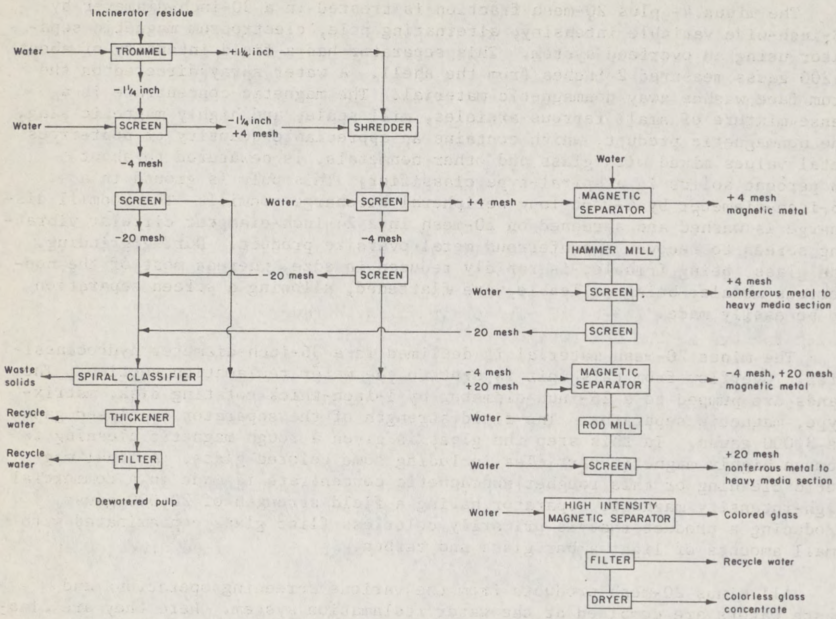

FIGURE 2. - Physical Beneficiation Flowsheet for Concentrating Valuable Materials Contained in Incinerator Residues.

screening operation where it is washed on a 30-inch-diameter vibrating screen fitted with both 4- and 20-mesh screens. The plus 4-mesh oversize material is discharged to a vibrating conveyor which spreads the material and underfeeds a 30-inch-diameter by 14-inch-wide, alternating pole, permanent magnet drum-type separator. The magnet has a field strength of about 500 gauss measured 2 inches from the shell. A water spray gives the material adhering to the magnet a final wash, leaving a clean iron product. The nonmagnetic fraction is composed of relatively large pieces of nonferrous metal, glass, and other nonmetals. To recover the nonferrous metals, this fraction is fed to a 10-hp hammermill having 20 swing hammers rotating at a peripheral speed of about 8,500 fpm. The hammermill, which is fitted with only one 2- by 8-inch discharge opening, breaks up most of the glass and other nonmetals. The hammermill discharge is screened and washed on a 24-inch-diameter circular vibrating screen fitted with both 4- and 20-mesh screens. The plus 4-mesh material is recovered as a nonferrous metal concentrate. This fraction represents about 75 percent of the recoverable nonferrous metals, and when obtained from well-burned residues will contain at least 96 percent metallics.

The minus 4- plus 20-mesh fraction is treated in a 30-inch-diameter by 18-inch-wide variable intensity, alternating pole, electrodrum magnetic separator using an overfeed system. This separator has a field intensity of about 1,200 gauss measured 2 inches from the shell. A water spray directed on the drum face washes away nonmagnetic material. The magnetic concentrate is a dense mixture of small ferrous articles, mill scale, and highly magnetic slag. The nonmagnetic product, which contains an appreciable quantity of nonferrous metal values mixed with glass and other nonmetals, is dewatered to about 60 percent solids in a spiral-type classifier. This pulp is ground in a 16-inch-diameter by 4-foot-long peripheral discharge rodmill. The rodmill discharge is washed and screened on 20-mesh in a 24-inch-diameter circular vibrating screen to recover a nonferrous metal oversize product. During grinding, the glass, being friable, is rapidly reduced in size, whereas most of the nonferrous metals, being malleable, are flattened, allowing a screen separation to be easily made.

The minus 20-mesh material is deslimed in a 36-inch-diameter hydroclassifier. Overflow from this unit is sent to the water reclamation section. The sands are pumped to a 26-inch-diameter by 1-inch-thick rotating disk, matrix-type, magnetic separator. The field strength of the separator in closed gap is 3,000 gauss. In this step the glass is given a rough magnetic cleaning to remove highly magnetic particles including some colored glass. A final magnetic cleaning of this rougher nonmagnetic concentrate is made in a commercial high-intensity magnetic separator having a field strength of 20,000 gauss, producing a product that is primarily colorless flint glass contaminated with small amounts of light amber glass and carbon.

All minus 20-mesh products from the various screening operations and waste waters are combined at the water reclamation system. Here they are classified in a 10-inch-diameter by 7-foot spiral classifier to remove slimes. The slime then is flocculated and thickened in a 3-foot-diameter by 3-foot-deep thickener. The overflow is filtered on an 18-inch-diameter by 12-inch vacuum drum filter. Clean overflow is recycled as wash water. Both the sand and slime products contain significant amounts of carbon, alumina, potash, and phosphorus.

MATERIALS BALANCE

Based on data developed in the continuous beneficiation plant, a materials balance for a plant processing 1,400 pounds of wet residues (1,000 pounds dry) per hour is given in table 1.

Operation of the plant when feeding 1,000 pounds of residue solids per hour will yield approximately 166 pounds of large ferrous metal (per hour), composed principally of wire, massive iron, and shredded cans. The magnetic material recovered from the minus 4-mesh fraction of the residues, which is composed principally of small iron particles, mill scale, and highly magnetic slag, amounts to about 139 pounds per hour. The total ferrous fraction accounts for about 30.5 percent of the feed. The total production of mixed nonferrous metal concentrate amounts to nearly 28 pounds per hour. During the processing operation, approximately 289 pounds of colorless glass concentrate and 207 pounds of magnetic glass are produced per hour; the two glass fractions account for almost 50 percent of the feed. The minus 20-mesh fraction of the residue, which includes the slime, amounts to only 17.1 percent of the feed.

TABLE 1. - Materials balance for continuous incinerator residue processing plant

Products recovered	Materials produced		
	Pounds per hour	Weight-percent	Cumulative weight-percent
Massive iron and wire	30	3.0	3.0
Plus 4-mesh magnetics	136	13.6	16.6
Plus 4-mesh nonferrous metals	17	1.7	18.3
Minus 4- plus 20-mesh magnetics	139	13.9	32.2
Minus 4- plus 20-mesh nonferrous metals	11	1.1	33.3
Minus 20-mesh nonmagnetic glass	289	28.9	62.2
Minus 20-mesh magnetic glass	207	20.7	82.9
Minus 20-mesh classifier sands	159	15.9	98.8
Thickener slimes	12	1.2	100.0
Composite	1,000	100.0	-

As shown in table 2, the quantity of water required for all of the washing operations is approximately 15.8 gallons per minute when processing residues at a feed rate of 1,000 pounds per hour. Since the incoming residues contain considerably more water than is retained in the products, the plant can be operated with zero net water consumption. In this size plant it has not been possible to define problems that may arise owing to buildup of soluble salts. Extended periods of operation in a much larger plant would be required to obtain reliable information of this type.

TABLE 2. - Wash water requirements for pilot plant continuous processing of incinerator residues

Washer location	Water required, gallons per min
Trommel	2.6
Primary screen	.8
Secondary screen	1.4
Permanent drum magnet	.4
Secondary shredder and nonferrous metal screen	.8
Electrodrum magnet	3.5
Rodmill screen	2.5
Matrix magnetic separator	3.8
Total	15.8

REFINING AND UTILIZATION OF RECLAIMED PRODUCTS

The refining of metals and minerals recovered from municipal incinerator residues into products suitable for commerce is also a prime objective of the research. At the Bureau's College Park Metallurgy Research Center, several methods for refining the iron fractions, which contain small amounts of copper and tin, to produce a marketable-grade product suitable as electric furnace feed stock have shown considerable promise. Preliminary tests indicate that an excellent separation of a high-quality aluminum product from the mixed nonferrous metals can be made using heavy media techniques. The sink fraction is a copper-rich product containing zinc, lead, tin, and small amounts of stainless steel. Heavy media processing, while not part of this experimental plant, is included in cost estimates for the larger plants. Compositions of typical products obtained by heavy media separation are given in table 3, and the flowsheet is shown in figure 3.

TABLE 3. - Compositions of products separated by heavy media

Product	Analysis, percent					
	Al	Zn	Cu	Pb	Sn	Fe
2.75 SPECIFIC GRAVITY						
Plus 4-mesh float..........	96.0	0.5	0.57	0.2	0.036	0.94
Plus 4-mesh sink...........	4.4	34.3	54.8	2.7	.35	.3
Minus 4- plus 20-mesh float	98.0	.17	.16	.1	.027	1.1
Minus 4- plus 20-mesh sink.	4.3	34.3	49.6	3.6	1.06	.26
2.95 SPECIFIC GRAVITY						
Plus 4-mesh float..........	96.0	0.16	0.33	0.1	0.034	1.2
Plus 4-mesh sink...........	1.7	41.1	47.2	3.7	.34	.22
Minus 4- plus 20-mesh float	97.0	.25	.27	.2	.058	1.0
Minus 4- plus 20-mesh sink.	.86	36.5	49.2	10.0	1.06	.14

Reclamation of useful glass products has also shown considerable promise. The fine-size colorless glass concentrates are already of a quality that would be acceptable as cullet by the glass industry. Additional efforts are being made to improve this product.

Research is also being conducted at the Bureau's Tuscaloosa Metallurgy Research Laboratory to determine the feasibility of making such products as bricks and glass wool from the magnetic glass concentrate recovered by the high-intensity units. Attractive bricks have been made in various colors that meet ASTM specifications for "severe weather" facing brick.

The sorting of glass by colors using commercially available electronic sorters is a relatively recent development. The first attempts to utilize this type of machine for sorting glass were made at the request of the Bureau of Mines which supplied the first samples in the form of typical glass recovered from incinerator residues. In view of the success of these initial tests, the Bureau purchased the first of these machines to be used for sorting colorless glass concentrates from both incinerated and unburned waste glass.

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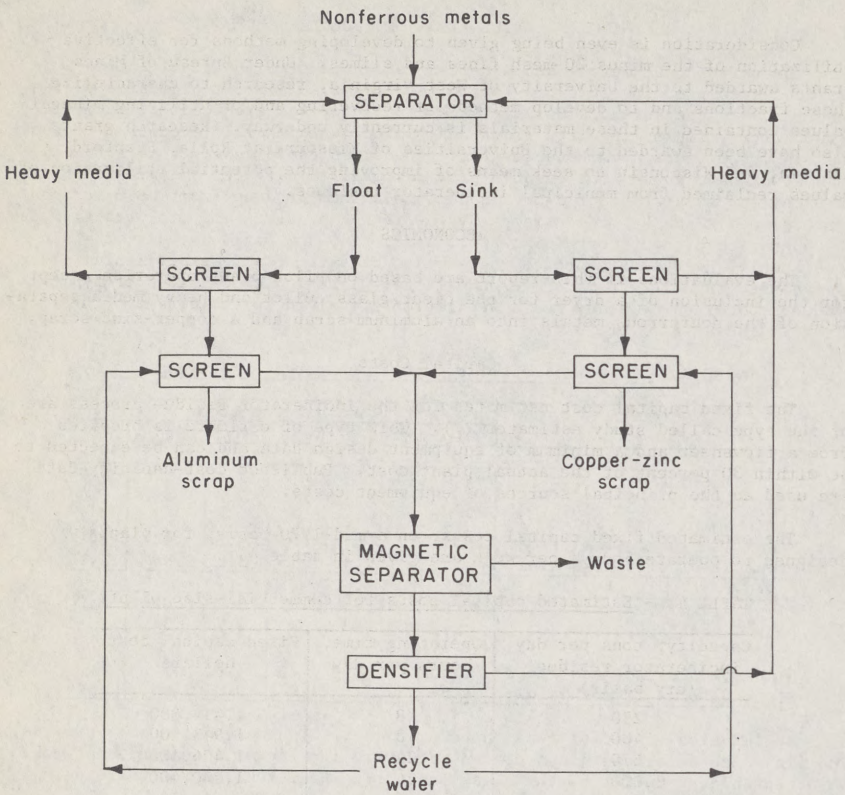

FIGURE 3. - Heavy Media Separation of Nonferrous Metals.

The electronic sorter is not yet a part of the flowsheet for treating incinerator residues. Instead it is being used in batch testing to determine its potential as a means for preconcentrating the colorless glass contained in the minus 1-1/4-inch plus 4-mesh fraction of incinerated glass. Excellent results are being obtained. Concentrate quality of 85 to 90 percent as determined by grain count can easily be achieved in single-stage processing with recoveries of 80 to 85 percent. Higher capacities, higher recoveries, and improved quality can be achieved by two or more stages of processing such as roughing and cleaning the concentrate or scalping a high-quality concentrate and scavenging the tails.

Consideration is even being given to developing methods for effective utilization of the minus 20-mesh fines and slimes. Under Bureau of Mines grants awarded to the University of West Virginia, research to characterize these fractions and to develop methods of recovering and/or utilizing mineral values contained in these materials is currently underway. Research grants also have been awarded to the Universities of Missouri at Rolla, Stanford, Alabama, and Wisconsin to seek means of improving the potential utilization of values reclaimed from municipal incinerator residues.

ECONOMICS

The evaluations in this report are based on pilot plant operation except for the inclusion of a dryer for the clear glass cullet and heavy media separation of the nonferrous metals into an aluminum scrap and a copper-zinc scrap.

Capital Costs

The fixed capital cost estimates for the incinerator residue process are of the type called study estimates (7). This type of estimate is prepared from a flowsheet and a minimum of equipment design data and can be expected to be within 30 percent of the actual plant cost. Published cost-capacity data are used as the principal sources of equipment costs.

The estimated fixed capital costs, on a mid-1970 basis, for plants designed to operate 5 days per week are given in table 4.

TABLE 4. - Estimated capital costs for commercial-size plants

Capacity, tons per day incinerator residue (dry basis)	Operating time, hours per day	Fixed capital cost, dollars
250	8	1,414,800
400	8	1,943,100
670	24	1,406,100
1,000	24	1,730,400

Operating Costs

The estimated operating costs are based on a 260-day operating year. Included in the direct operating costs are raw materials, utilities, labor, maintenance, payroll overhead, and operating supplies. Indirect costs include plant overhead, control laboratories, safety, and plant protection. Fixed costs include insurance and depreciation. No local taxes are included in the fixed costs because it is assumed the plants will be operated by a city or State government.

Operating costs of all four plants are shown in dollars per ton of dry incinerator residue fed to the plant. These costs represent the cost of separating the incinerator residue into ferrous metal, aluminum scrap, copper-zinc scrap, and glass fractions.

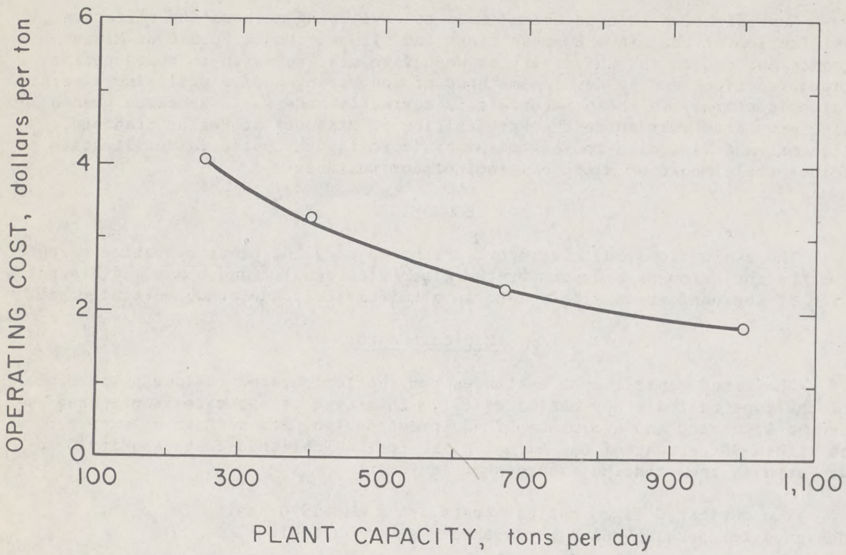

FIGURE 4. - Estimated Operating Cost (Dry Residue Basis).

The variation of operating cost with processing plant capacity is shown in figure 4. Plants smaller than 500 tons per day of residue (dry basis) operate only 8 hours per day, and at this size minimum labor requirement controls the cost. The estimated operating costs for the four plants are given in table 5. More detailed estimates are given in the appendix.

TABLE 5. - Estimated operating costs for commercial-size plants

Capacity, tons per day incinerator residue (dry basis)	Operating time, hours per day	Operating costs, dollars per ton of dry residue
250	8	4.06
400	8	3.28
670	24	2.32
1,000	24	1.80

Product Values

The estimated product values are given in table 6; these values were established following discussions with representatives of the primary and secondary materials industries, as well as major engineering firms engaged in development of urban waste recycling systems.

TABLE 6. - Estimated product values

Product	Value	Quantity per ton of residue, lb	Values per ton of residue, dollars
Ferrous metal..	$10/ton	610	3.05
Aluminum.......	$0.12/lb	32	3.84
Copper-zinc....	$0.19/lb	24	4.56
Colorless glass	$12/ton	552	3.31
Colored glass..	$5/ton	398	1.00
Total.......	-	-	15.76

SUMMARY AND FUTURE PLANS

The Bureau of Mines has developed and demonstrated a technically feasible method for processing incinerator residues on a continuous basis to reclaim the contained metal and mineral values. The flowsheet is straightforward and utilizes conventional and proven mineral engineering equipment. The entire process comprises simply a series of shredding, screening, grinding, and magnetic separation procedures. Based on the engineering data developed in the continuous 1,000-pound-per-hour processing plant, estimates for capital and operating costs for commercial-size plants show favorable economics.

Significant progress also has been made in developing processes for refining and upgrading the various products reclaimed from incinerator residues. While work in some cases remains to be done to reach the ultimate objective of converting the reclaimed materials into products suitable for recycling, the keen interest shown by industry has been encouraging.

The major urban refuse solid waste research effort by the Bureau is now focused on the development of an economical process for mechanically separating metals, glass, paper, and plastics from raw refuse on a continuous basis. The first step in this new process will be to liberate all of the materials in the refuse by coarse shredding in a double-opposed chain mill. Various combinations of air classification, magnetic separation, screening, optical sorting, electrostatic separation, and gravity concentration will then be used to separate and reclaim the values. Although two stages of shredding may be required, every effort will be made to avoid fine shredding and grinding since the cardinal rule in all physical beneficiation is to make the required separations on the largest size of material possible. Most of the major equipment required for this new pilot plant has been purchased and delivered and will be installed at Edmonston, Md., and operating by mid-1971.

Studies to determine the effectiveness of various air classification systems (1) to separate the organic and inorganic fractions of shredded raw refuse are in progress. Samples of the inorganic fractions, principally metals and glass, separated by a number of air classification schemes as well as by a pulping technique, have been characterized.

REFERENCES

1. Chindgren, C. J., K. C. Dean, and LeRoy Peterson. Recovery of the Nonferrous Metals From Auto Shredder Rejects by Air Classification. BuMines Tech. Prog. Rept. 31, 1971, 11 pp.

2. Kenahan, C. B., and P. M. Sullivan. Let's Not Overlook Salvage. APWA Reporter, v. 34, No. 3, March 1967, pp. 5-8.

3. Kenahan, C. B., P. M. Sullivan, J. A. Ruppert, and E. F. Spano. Composition and Characteristics of Municipal Incinerator Residues. BuMines Rept. of Inv. 7204, 1968, 22 pp.

4. Rampacek, Carl. Reclaiming and Recycling Metals and Minerals Found in Municipal Incinerator Residues. Illinois Inst. of Technol. Res. Inst. (IITRI), Mineral Waste Utilization, Mar. 28, 1968, pp. 124-131.

5. Stanczyk, M. H., and J. A. Ruppert. Continuous Physical Beneficiation of Metals and Minerals Contained in Municipal Incinerator Residues. Illinois Inst. of Technol. Res. Inst. (IITRI), Symposium on Solid Waste, Mar. 18-19, 1970, pp. 255-262.

6. Stanczyk, M. H., and P. M. Sullivan. Physical and Chemical Beneficiation of Metal and Mineral Values Contained in Incinerator Residues. AIME Annual Meeting, Preprint 69-B-54, Feb. 16-20, 1969, 12 pp.

7. Weaver, J. B., H. C. Bauman, and W. F. Heneghan. Cost and Profitability Estimation. Sec. in Perry's Chemical Engineers' Handbook, ed. by R. H. Perry, C. H. Chilton, and S. D. Kirkpatrick. McGraw-Hill Book Co., Inc., New York, 4th ed., 1963, p. 26-5.

APPENDIX

TABLE A-1. - Estimated annual operating cost, 250-tpd incinerator residue plant--8-hour day

	ANNUAL COST	COST PER TON INCINERATOR RESIDUE
DIRECT COST-		
RAW MATERIALS-		
INCINERATOR RESIDUE		
AT $0. PER TON....................	$ 0	$ 0.
FLOCCULANT AT $1.60 PER POUND.......	2200	0.03
FERROSILICON AT $0.07 PER POUND.....	100	0.01
REPLACEMENT RODS FOR ROD MILL		
AT $0.12 PER POUND................	1000	0.02
TOTAL...........................	3300	0.06
UTILITIES-		
ELECTRIC POWER AT 1 CENT PER KWHR...	4700	0.07
WATER, PROCESS AT 47 CENTS PER MGAL.	800	0.01
NATURAL GAS AT 50 CENTS PER MMBTU...	8700	0.13
TOTAL...........................	14200	0.21
DIRECT LABOR-		
LABOR AT $2.50 PER HOUR.............	36400	0.56
SUPERVISION, 25 PERCENT OF LABOR....	9100	0.14
TOTAL...........................	45500	0.70
PLANT MAINTENANCE-		
LABOR...............................	29400	0.45
SUPERVISION, 25 PERCENT OF		
MAINTENANCE LABOR.................	7400	0.11
MATERIALS...........................	24600	0.38
TOTAL...........................	61400	0.94
PAYROLL OVERHEAD, 25 PERCENT OF		
ABOVE PAYROLL.......................	20600	0.32
OPERATING SUPPLIES, 20 PERCENT OF		
PLANT MAINTENANCE...................	12300	0.19
TOTAL DIRECT COST...............	157300	2.42
INDIRECT COST, 20 PERCENT OF		
DIRECT LABOR AND MAINTENANCE...........	21400	0.33
FIXED COST-		
INSURANCE, 1.0 PERCENT OF TOTAL		
PLANT COST..........................	14100	0.22
DEPRECIATION, 20 YEAR LIFE............	70700	1.09
TOTAL OPERATING COST...........	263500	4.06

TABLE A-2. - Estimated annual operating cost, 400-tpd incinerator residue plant--8-hour day

	ANNUAL COST	COST PER TON INCINERATOR RESIDUE
DIRECT COST-		
RAW MATERIALS-		
INCINERATOR RESIDUE		
AT $0. PER TON	$ 0	$ 0.
FLOCCULANT AT $1.60 PER POUND	3500	0.03
FERROSILICON AT $0.07 PER POUND	100	0.01
REPLACEMENT RODS FOR ROD MILL		
AT $0.12 PER POUND	1600	0.02
TOTAL	5200	0.06
UTILITIES-		
ELECTRIC POWER AT 1 CENT PER KWHR	6900	0.07
WATER, PROCESS AT 47 CENTS PER MGAL.	1300	0.01
NATURAL GAS AT 50 CENTS PER MMBTU	13900	0.13
TOTAL	22100	0.21
DIRECT LABOR-		
LABOR AT $2.50 PER HOUR	36400	0.35
SUPERVISION, 25 PERCENT OF LABOR	9100	0.09
TOTAL	45500	0.44
PLANT MAINTENANCE-		
LABOR	40200	0.39
SUPERVISION, 25 PERCENT OF		
MAINTENANCE LABOR	10100	0.10
MATERIALS	33300	0.32
TOTAL	83600	0.81
PAYROLL OVERHEAD, 25 PERCENT OF		
ABOVE PAYROLL	24000	0.23
OPERATING SUPPLIES, 20 PERCENT OF		
PLANT MAINTENANCE	16700	0.16
TOTAL DIRECT COST	197100	1.91
INDIRECT COST, 20 PERCENT OF		
DIRECT LABOR AND MAINTENANCE	25800	0.25
FIXED COST-		
INSURANCE, 1.0 PERCENT OF TOTAL		
PLANT COST	19400	0.19
DEPRECIATION, 20 YEAR LIFE	97200	0.93
TOTAL OPERATING COST	339500	3.28

TABLE A-3. - Estimated annual operating cost, 670-tpd incinerator residue plant--24-hour day

	ANNUAL COST	COST PER TON INCINERATOR RESIDUE
DIRECT COST-		
RAW MATERIALS-		
INCINERATOR RESIDUE		
AT $0. PER TON....................	$ 0	$ 0.
FLOCCULANT AT $1.60 PER POUND.......	5800	0.03
FERROSILICON AT $0.07 PER POUND.....	200	0.01
REPLACEMENT RODS FOR ROD MILL		
AT $0.12 PER POUND................	2700	0.02
TOTAL.........................	8700	0.06
UTILITIES-		
ELECTRIC POWER AT 1 CENT PER KWHR...	12100	0.07
WATER, PROCESS AT 47 CENTS PER MGAL.	2200	0.01
NATURAL GAS AT 50 CENTS PER MMBTU...	23900	0.14
TOTAL.........................	38200	0.22
DIRECT LABOR-		
LABOR AT $2.50 PER HOUR............	98800	0.57
SUPERVISION, 25 PERCENT OF LABOR....	24700	0.14
TOTAL.........................	123500	0.71
PLANT MAINTENANCE-		
LABOR..............................	28700	0.16
SUPERVISION, 25 PERCENT OF		
MAINTENANCE LABOR................	7200	0.04
MATERIALS..........................	24000	0.14
TOTAL.........................	59900	0.34
PAYROLL OVERHEAD, 25 PERCENT OF		
ABOVE PAYROLL......................	39900	0.23
OPERATING SUPPLIES, 20 PERCENT OF		
PLANT MAINTENANCE..................	12000	0.07
TOTAL DIRECT COST.............	282200	1.63
INDIRECT COST, 20 PERCENT OF		
DIRECT LABOR AND MAINTENANCE...........	36700	0.21
FIXED COST-		
INSURANCE, 1.0 PERCENT OF TOTAL		
PLANT COST.........................	14100	0.08
DEPRECIATION, 20 YEAR LIFE............	70300	0.40
TOTAL OPERATING COST...........	403300	2.32

TABLE A-4. - Estimated annual operating cost, 1,000-tpd incinerator residue plant--24-hour day

	ANNUAL COST	COST PER TON INCINERATOR RESIDUE
DIRECT COST-		
RAW MATERIALS-		
INCINERATOR RESIDUE AT $0. PER TON	$ 0	$ 0.
FLOCCULANT AT $1.60 PER POUND	8600	0.03
FERROSILICON AT $0.07 PER POUND	300	0.01
REPLACEMENT RODS FOR ROD MILL AT $0.12 PER POUND	4000	0.02
TOTAL	12900	0.06
UTILITIES-		
ELECTRIC POWER AT 1 CENT PER KWHR	17000	0.07
WATER, PROCESS AT 47 CENTS PER MGAL	3300	0.01
NATURAL GAS AT 50 CENTS PER MMBTU	35500	0.14
TOTAL	55800	0.22
DIRECT LABOR-		
LABOR AT $2.50 PER HOUR	98800	0.38
SUPERVISION, 25 PERCENT OF LABOR	24700	0.09
TOTAL	123500	0.47
PLANT MAINTENANCE-		
LABOR	35400	0.14
SUPERVISION, 25 PERCENT OF MAINTENANCE LABOR	8900	0.03
MATERIALS	29300	0.11
TOTAL	73600	0.28
PAYROLL OVERHEAD, 25 PERCENT OF ABOVE PAYROLL	42000	0.16
OPERATING SUPPLIES, 20 PERCENT OF PLANT MAINTENANCE	14700	0.06
TOTAL DIRECT COST	322500	1.25
INDIRECT COST, 20 PERCENT OF DIRECT LABOR AND MAINTENANCE	39400	0.15
FIXED COST-		
INSURANCE, 1.0 PERCENT OF TOTAL PLANT COST	17300	0.07
DEPRECIATION, 20 YEAR LIFE	86500	0.33
TOTAL OPERATING COST	465700	1.80

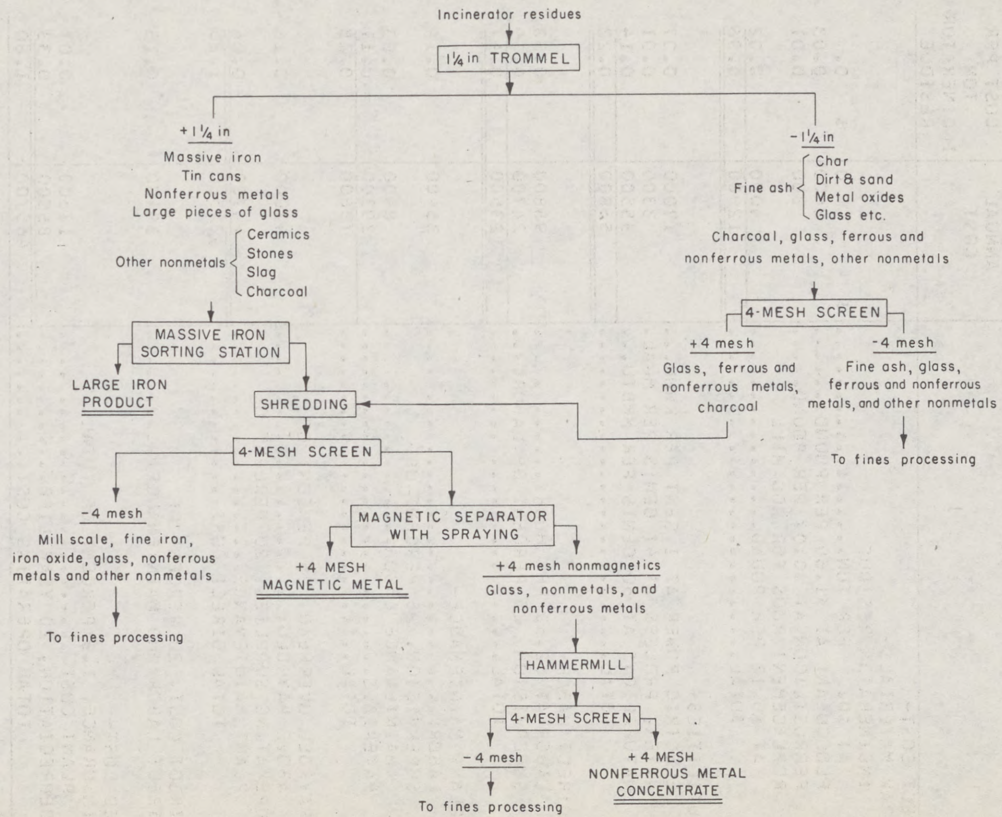

FIGURE A-1. - Physical Beneficiation Flowsheet for Coarse-Size Residues.

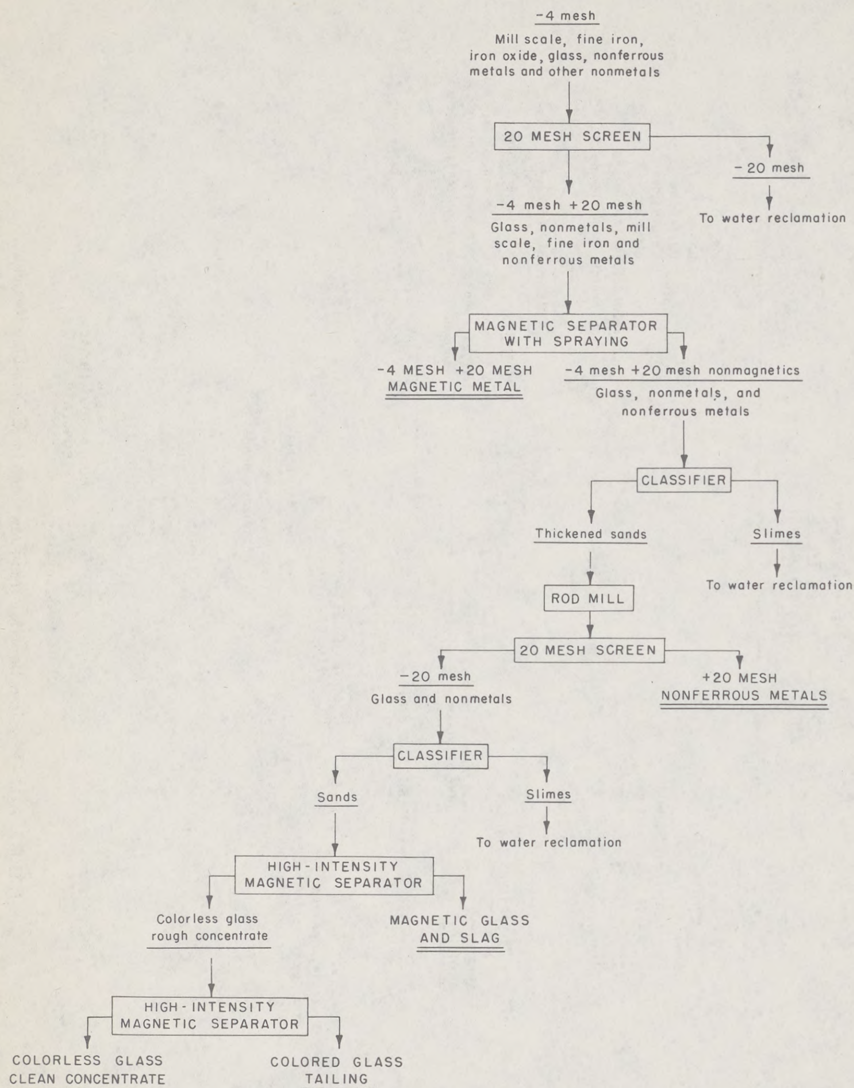

FIGURE A-2. - Physical Beneficiation Flowsheet for Intermediate-Size Residues.

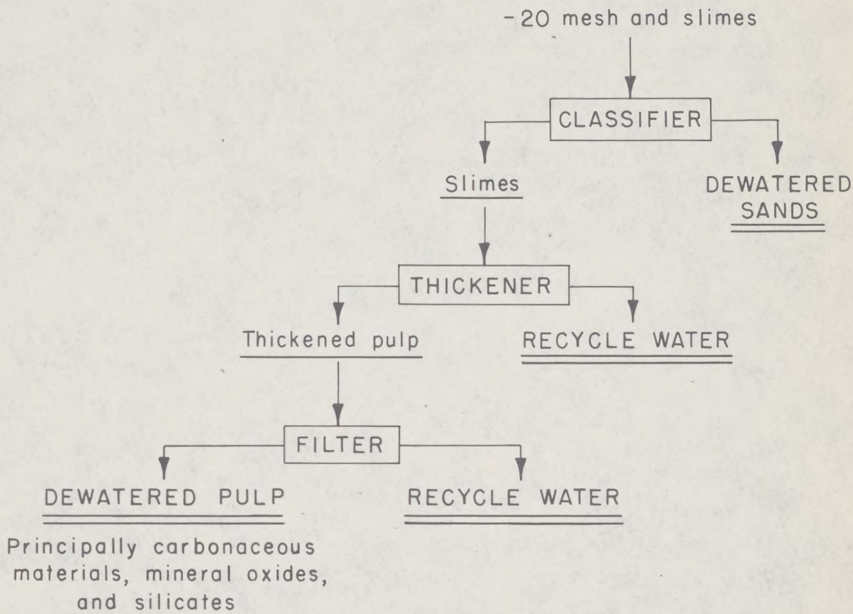

FIGURE A-3. - Physical Beneficiation Flowsheet for Fine-Size Residues and Water Reclamation.

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PRELIMINARY SEPARATION OF METALS AND NONMETALS FROM URBAN REFUSE

by

K. C. Dean,[1] C. J. Chindgren,[2] and LeRoy Peterson[3]

ABSTRACT

Horizontal and vertical air classification systems were tested individually and in simulated tandem use for the recovery of ferrous and nonferrous metals and of other noncombustible and combustible products from shredded urban refuse. The horizontal air system with a larger tonnage throughput was used to obtain preliminary separations, and a smaller capacity vertical system was used as a cleaning device.

Air elutriation, magnetic separation, and screening of shredded minus 6-inch municipal refuse recovered 92 percent of the metal in a relatively clean iron product contaminated only by adhering coatings or entrapped materials, recovered 97 percent of the combustibles in a 97-percent combustible product, and rejected 88 percent of the nonmetal noncombustibles. Cleaning of the preliminary combustible fraction produced a 98-percent paper product while rejecting other combustibles (plastics, rubber, textiles, etc.) into a 94-percent combustible product. Retreatment of the preliminary noncombustible fraction produced a relatively clean glass product.

INTRODUCTION

The daily per capita discard of domestic, municipal, and commercial components of urban refuse amounts to 3.5, 1.2, and 2.3 pounds, respectively.[4] This total quantity of 7.0 pounds per capita per day is equal to a national total of 256 million tons per year. Approximately 225 million tons of urban refuse is disposed of in landfills, and salvage of materials from these landfills is discouraged by health authorities. About 30 million tons is burned in municipal incinerators. An annual composite urban refuse could produce about 12 million tons of ferrous metals, over a million tons of nonferrous

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[1] Project coordinator.
[2] Chemical research engineer.
[3] Chemical engineer.
All authors are with the Salt Lake City Metallurgy Research Center, Bureau of Mines, Salt Lake City, Utah.
[4] Office of Science and Technology. Solid Waste Management. A Comprehensive Assessment of Solid Waste Problems, Practices, and Needs. May 1969, 111 pp.

metals, and 15 million tons of glass. The College Park Metallurgy Research Center of the Bureau of Mines[5] has developed procedures for recovering metals, glass, and other products from incinerator residues. Bureau researchers are now working on a parallel system to recover similar values from raw, unburned refuse in addition to the paper and plastic components. This report describes a portion of that study.

In other related solid waste research two air classification systems were designed and built to aid in the recovery of nonferrous metals from the nonmagnetic reject material from auto shredding operations. These systems were used singly or jointly to recover over 92 percent of the metal content from this material.[6] This useful adaptation of air classification or winnowing, to achieve separation and recovery of valuable components, prompted the testing of these systems on urban refuse. This report summarizes the findings as to the potential of air winnowing as a preliminary separation medium for treating shredded raw refuse.

QUANTITY AND COMPOSITION OF A TYPICAL URBAN REFUSE

Procurement of small representative samples of urban wastes is extremely difficult considering the great variability in discarded materials and collection points. Fortunately, fairly representative samples for laboratory elutriation testing were obtained by cooperating with the city of Madison, Wis., and the Heil Co., who have cooperatively studied the shredding and landfill disposal of urban refuse since 1966.[7] Madison is a representative city as to the quantity of refuse discarded in that the per capita per year discard is about 1.3 tons, compared with the 1.2-ton national average. However, other urban wastes may vary considerably from the Madison refuse in composition.

Three drums of approximately minus 6-inch shredded raw refuse weighing 314 pounds were received for preliminary separatory testing in the air elutriation systems. The refuse was shredded in two types of mills, a Tollemache vertical shaft and Gondard horizontal shaft mill, with respective capacities of about 15 and 9 tons per hour.[8] The samples were transported in plastic bags to prevent moisture loss during shipping and storage. The wide range in the metal content of the refuse was exemplified in the three drums received, which contained from 4.3 to 10.2 percent metal. Analysis of the overall sample is presented in table 1.

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[5] Sullivan, P. M., and M. H. Stanczyk. Economics of Recycling Metals and Minerals From Urban Refuse. BuMines Tech. Prog. Rept. 33, 1971, 19 pp.

[6] Chindgren, C. J., K. C. Dean, and LeRoy Peterson. Recovery of the Nonferrous Metals From Auto Shredder Rejects by Air Classification. BuMines Tech. Prog. Rept. 31, 1971, 11 pp.

[7] Reinhardt, John J. City of Madison Public Works Department Takes Active Lead in Finding Solutions to Solid Waste Problems. Waste Age, v. 1, No. 5, September-October 1970, pp. 20-40.

[8] Reference to specific equipment is made to facilitate understanding and does not imply endorsement by the Bureau of Mines.

TABLE 1. - Characterization of Madison refuse samples

	Analysis, percent
Metal:	
Ferrous	5.7
Nonferrous	.3
Moisture[1]	12.4
Nonmetal:	
Paper	41.0
Cardboard	15.3
Cloth and leather	4.4
Plastic	2.9
Wood and plants	1.5
Rubber	.6
Dirt and glass	15.9

[1]Varied between 5 and 30 percent on different lots.

A further characterization of the sample according to particle size was obtained by screening the air-dried materials. Complete separation of the paper and cardboard was not obtained by the hand-sorting techniques used, and their distribution should be considered as only approximate. The size distribution of the refuse materials is shown in table 2.

TABLE 2. - Screen-sized distribution of Madison refuse

	Component, weight-percent			
	-6 +1 inch	-1 inch +4 mesh	-4 mesh	Total
Metal:				
Ferrous	4.7	1.8	-	6.5
Nonferrous	.1	.2	-	.3
Total	4.8	2.0	-	6.8
Nonmetal:				
Paper	3.2	41.5	2.1	46.8
Cardboard	11.2	5.8	.5	17.5
Cloth and leather	4.8	.2	-	5.0
Plastic	2.5	.8	-	3.3
Wood	.5	1.1	.1	1.7
Rubber	.7	-	-	.7
Dirt and glass	-	2.3	15.9	18.2
Total	22.9	51.7	18.6	93.2

SELECTION OF A SEPARATION METHOD

Reuse of all reclaimable materials in municipal refuse is the ultimate goal of Bureau research, but the recovery of materials sufficiently clean for recycle to the individual originating industries is difficult to achieve. Hence, the preliminary goal, reported on herein, was the recovery of separate metallic, other noncombustible (glass, dirt, etc.), and combustible products

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only. Recovery of a high-grade shredded combustible product relatively free of metallics, glass, and dirt would enhance potential usage of the product as a source of heat and power with a minimal residual ash.

Separation of a clean paper product relatively free of plastics and other impurities would increase the possibility of recycle, but if heat and power from burning were desired, addition of the plastics would be desirable. Rubbish, garbage, typical city refuse, and coal, respectively, have approximate heating values in Btu per pound of 6,500, 8,750, 8,800, and 15,000.[9] Polyvinyl chloride and polyethylene plastics have respective heating values of about 10,000 and 20,000 Btu per pound, which would add appreciably to the overall heat value of refuse.

Results show that screening on 4 mesh removes over 87 percent of the dirt and glass in the sample, but only 3.6 percent of the total combined combustibles (paper, cardboard, cloth, leather, plastic, wood, and rubber) reports in the minus 4-mesh product. Thus, screening alone offers possibilities for achieving a good separation of materials; however, efficient screening of the raw refuse prior to air classification is difficult to accomplish because of the moisture content and therefore is best done after preliminary air elutriator separations are made.

The large quantities of paper and cardboard in urban refuse hinder the direct application of wet beneficiation procedures such as jigging, sink-float, tabling, water elutriation, and leaching for separating components because fibrous materials absorb large quantities of water. Conversely, the low density of paper, plastics, and cardboard is advantageous to air winnowing, which led to selection of this method for attaining preliminary separations.

EQUIPMENT

Two air classification systems were tested and evaluated in this preliminary study of separating urban refuse. Both a horizontal and a vertical type proved effective for making good separations. The pilot-plant horizontal blower system has a much higher tonnage throughput than the slightly more efficient vertical separator when treating low-density urban refuse. Hence, the horizontal blower with capacities ranging up to 1.5 tons per hour was preferred for initial rough separation.

Horizontal Elutriator

Figure 1 is a drawing of the horizontal air elutriating system. In this system, material is discharged from a variable-speed belt feeder into an enclosed sloping chute which enters the top of the elutriator. The discharge from the chute strikes a baffle which causes it to drop vertically into the horizontally moving air stream. The air stream is produced by an industrial-type LS centrifugal blower with a capacity of 1,030 standard cubic feet per minute (scf/min) at 8-inch water column pressure. The fan is driven at 2,800 rpm by a 3-hp motor. (A sliding gate on the blower inlet can be set to obtain air flows from 1,200 to 3,500 scf/min with static pressures ranging from 0.05 to 0.4 inch water column vacuum, respectively.)

[9] McGraw-Hill Book Co. Mark's Mechanical Engineering Handbook. New York, 1951, p. 772.

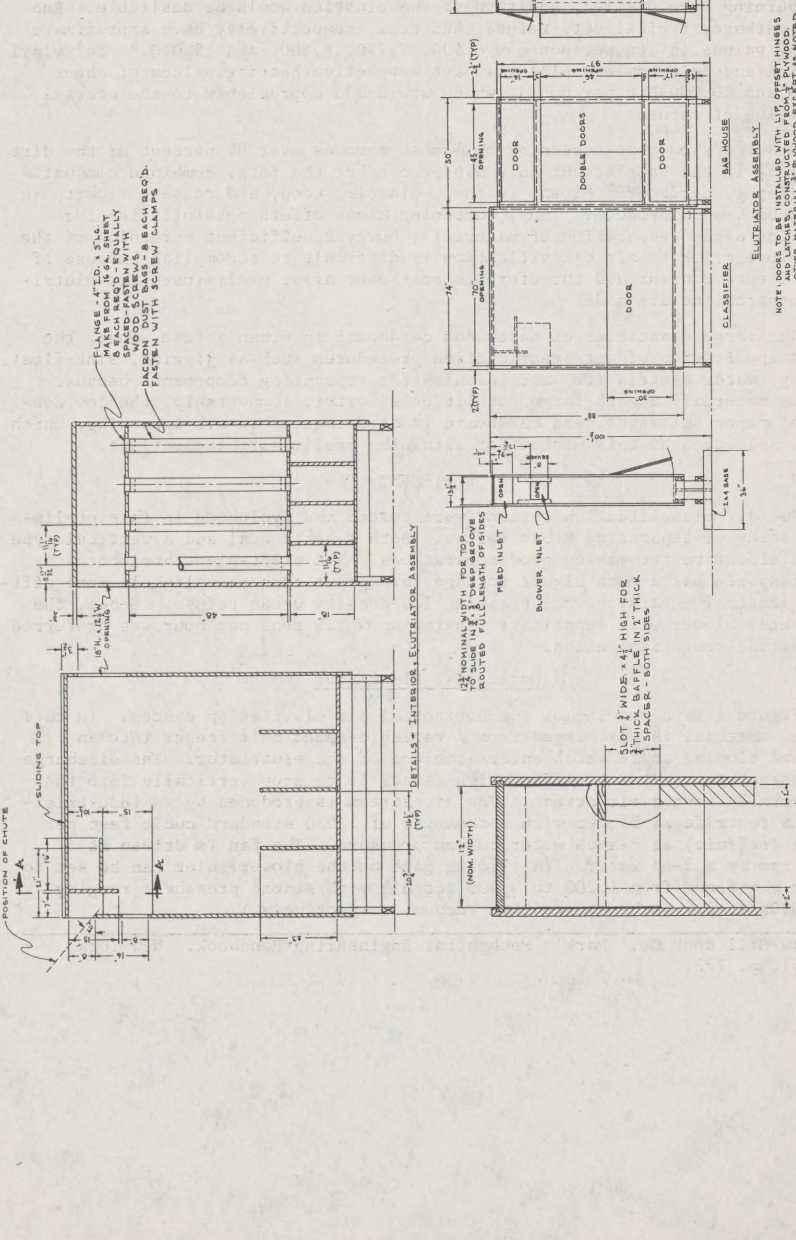


FIGURE 1. - Horizontal Air-Stream Elutriating System.

The blower has an 8-inch-square outlet set below the discharge chute, and the air stream blows the feed material into a 12-inch-wide by 6-foot-long compartmented chamber, open at the upper front end. The metals, plastics, hard rubber, and other materials of high density fall into the front compartments, and the paper, textiles, fibers, and light materials are collected in the compartments more distant from the blower. A baghouse located at the opposite end from the blower is used to collect the fines. The cost of constructing the horizontal air elutriator, less feeder, was $685, which includes $60 for materials, $150 for labor, and $475 for the blower.

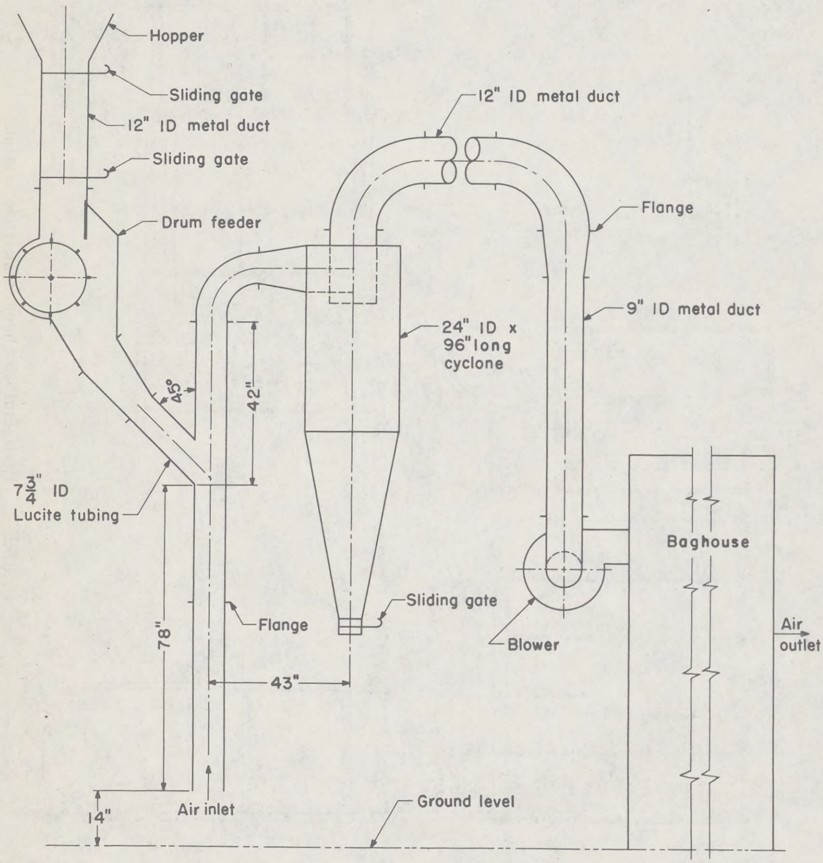


FIGURE 2. - Air Fluidizing Column for Processing Shredded Urban Refuse.

Vertical Elutriator

Figure 2 is a schematic drawing of the vertical elutriator. This equipment can be used to obtain a preliminary separation or to process middling fractions from the horizontal elutriator system. As a preliminary or rougher separator, the feed is added from a holding bin on the top end which drops the material onto a variable-speed drum serving as a feed regulator to the column. The material passes from the drum into a feeding chute attached at a 45° angle to the elutriating column about halfway up the tube. The material entering the column is elutriated in a rising air stream produced by the same centrifugal blower as used in the horizontal system. Heavier particles drop out the bottom of the column as the lighter material is carried upwards and into a cyclone for collection. The material collected in the bottom of the cyclone is periodically discharged through a bottom sliding gate. The cyclone collector is efficient so that only a negligible quantity of dust is carried back through the cyclone air outlet pipe to the blower. Figure 3 shows the horizontal and vertical air classifiers.

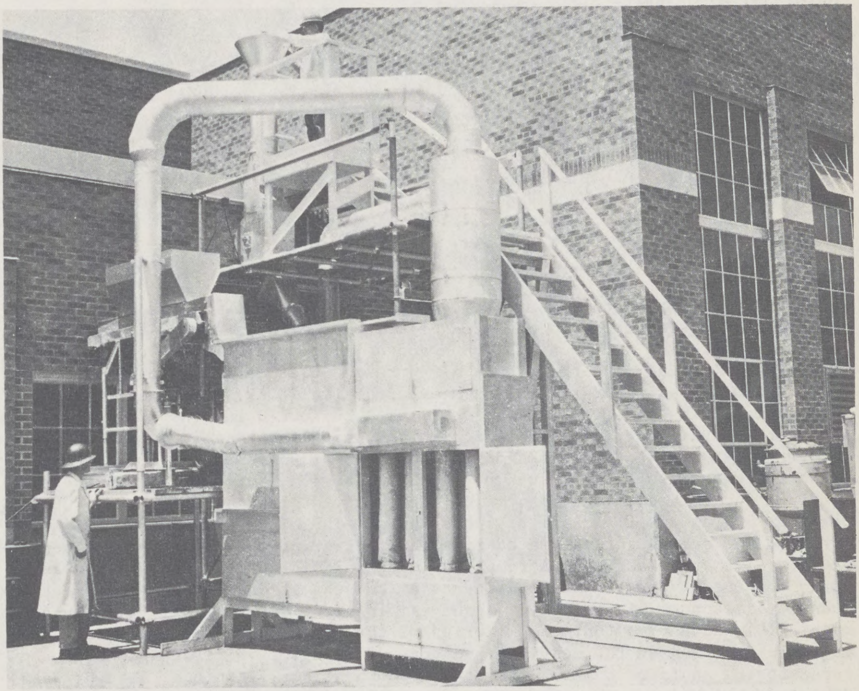


FIGURE 3. - Horizontal Air Elutriator and Vertical Air Classifier.

SEPARATION PROCEDURES

Initial air separation tests were run on 50-pound individual samples of the refuse in both the vertical and horizontal air elutriators. Although the initial tests showed the vertical classifier was capable of better separations at low feed rates than the horizontal type, the latter was selected for the initial separation because of its threefold to fourfold higher capacity. The vertical column was used for retreatment of the initial classified products. Air classification of raw refuse in the horizontal blower contributed an auxiliary benefit in that the refuse was partially dried by passage through the classifier and so eased feeding problems on retreatment in the vertical column.

A combination test based on the separation objective of producing metal, other noncombustible, and combustible concentrates and using information from preliminary tests as a guide was conducted on a 50-pound lot of shredded, raw, municipal refuse. This sample contained, in percent, 5.9 metal, 76.0 combustible, and 18.1 other noncombustibles. The head sample contained the following individual components:

	Percent
Metal................	5.9
Paper...............	45.1
Cardboard...........	16.0
Cloth and leather....	7.2
Plastic.............	4.7
Wood................	1.8
Rubber..............	1.2
Glass...............	10.4
Dirt................	7.7

The test sample containing about 15 percent moisture was fed into the horizontal classifier from a hand-fed belt feeder at a rate of 2,500 pounds per hour, employing a 3-inch bed depth and a 48-foot-per-minute belt speed. The refuse, falling into the blower air stream set at a flow rate of 1,300 scf/min, was separated into a heavy fraction (sink) which was collected in the first bin and a light fraction (float) collected in bins 2, 3, and 4, and in the baghouse. The heavy fraction was then magnetically separated to recover the iron, and the nonmagnetic fraction was screened on 4 mesh. The light fraction also was screened on 4 mesh. The plus 4-mesh fractions were combined and retreated in the vertical air elutriator at a rate of 800 pounds per hour and an air flow rate of 500 scf/min. The minus 4-mesh products were combined and subsequently treated in a water elutriation column for the separation of dirt and glass. No attempt was made in this study to show the distribution of the nonferrous metal content in the schematic flowsheet because the quantity in the sample, as well as the sample size, was too small to provide a meaningful accounting, but the majority of the nonferrous reported in the nonmagnetic fraction of the heaviest product. Future work will be conducted to separate the nonferrous metal from the noncombustible fractions. The procedure and separation results attained are presented in the flowsheet of figure 4.

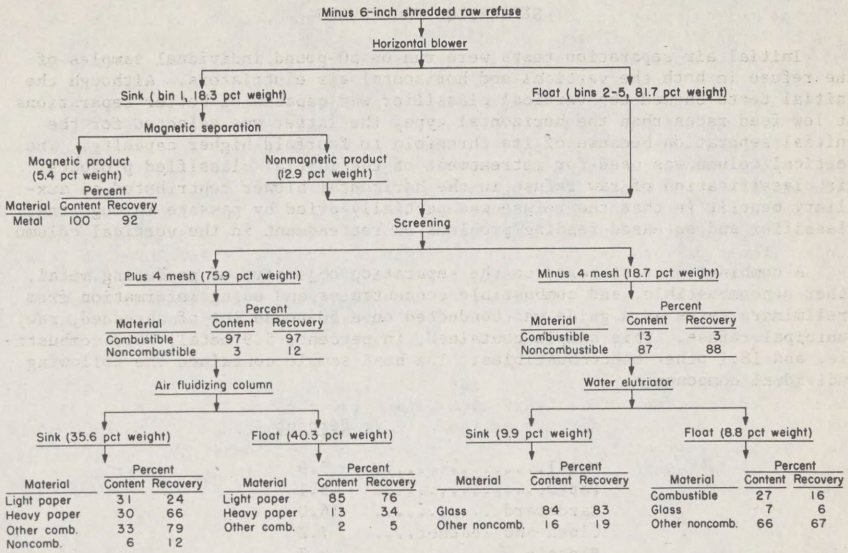


FIGURE 4. - Flowsheet for Reclamation of Shredded Raw Urban Refuse.

The summary of a single treatment of the raw refuse in the horizontal blower, followed by magnetic separation of the heavy product and screening of the other products, is given in table 3.

TABLE 3. - Product recovery from treated urban refuse

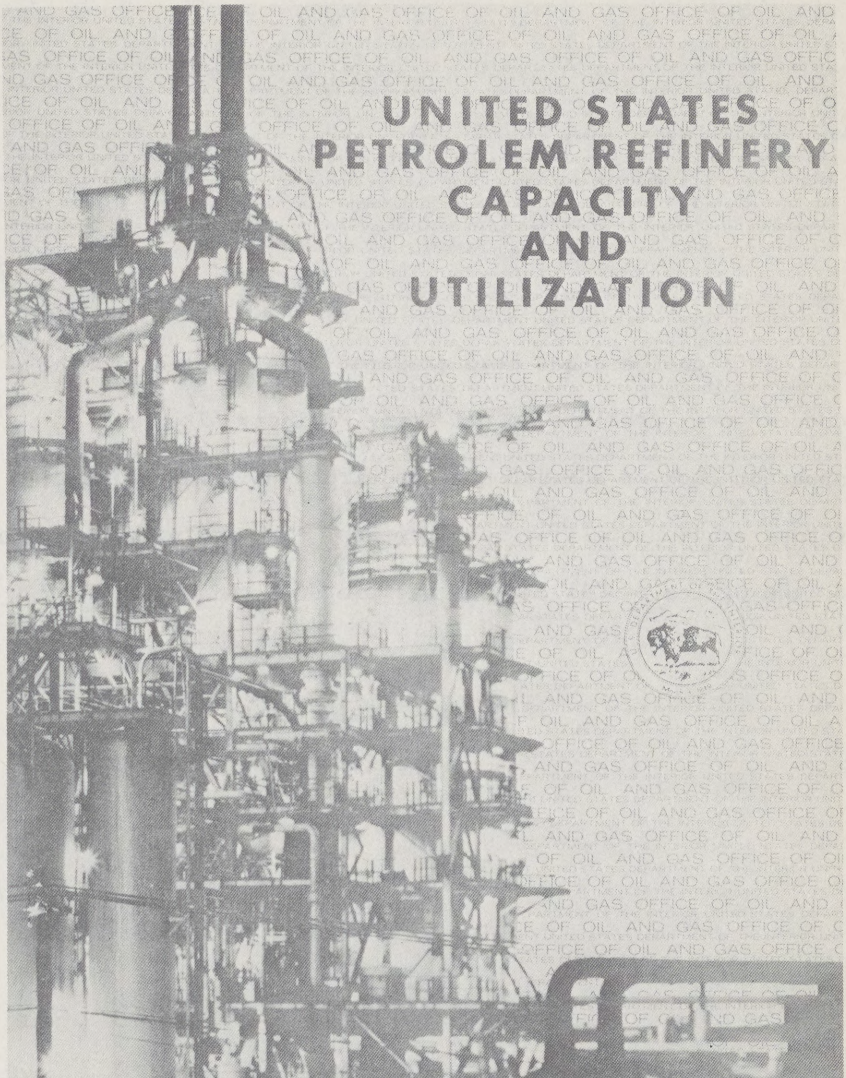
Product	Weight-percent	Content, percent			Distribution, percent		
		Metal	Noncomb.	Comb.	Metal	Noncomb.	Comb.
Metal...............	5.4	100	-	-	92	-	-
Elutriator product:							
Plus 4 mesh........	75.9	[1]<1	<3	97	8	12	97
Minus 4 mesh.......	18.7	-	87	13	-	88	3
Heads...............	100.0	5.9	18.1	76	100	100	100

[1]The 8 percent of the metal not recovered in the metal product constitutes less than 1 percent of the plus 4-mesh elutriated product.

The simple processing steps outlined were effective in recovering 92 percent of the metal in a clean product. The plus 4-mesh elutriated product represented 97-percent recovery of the combustibles and contained only 3 percent of noncombustible impurities. This product should be eminently satisfactory as a fuel. The minus 4-mesh elutriated product representing only 18.7 percent of the weight of the raw refuse could be discarded to landfill with only a 3-percent loss of the combustibles.

The initial plus and minus 4-mesh elutriated products were further treated in an effort to produce individual paper, glass, other combustible, and other noncombustible products. The combined plus 4-mesh elutriated product was further classified by passing the material through the vertical air fluidizing column to produce a relatively clean paper product. Figure 4 shows that the float product from this processing contained 85 percent light paper, 13 percent heavy paper, and 2 percent other combustibles. The other combustibles in this product consist of about 1.2 percent film plastic and 0.4 percent each of fabric and wood. Although a clean separation of light and heavy papers was not obtained, the product was 98 percent paper and 100 percent combustible and might be suitable for recycle. This product represented 41 percent of the total combustibles in the original refuse. The sink product from this operation was 94 percent combustible and would still be an acceptable fuel, producing only a modest amount of ash. Optimum operating conditions were not necessarily developed in this preliminary investigation and may be improved with subsequent testing.

The minus 4-mesh product from the initial air elutriation was subjected to water elutriation for recovery of a glass product from the other noncombustible materials. This test, as shown in figure 4, produced an 84-percent glass product representing 83-percent recovery of the glass. This glass product will be subjected to additional beneficiation tests in an attempt to produce a recyclable glass cullet product.


UNITED STATES
PETROLEM REFINERY
CAPACITY
AND
UTILIZATION

FOREWARD

This analysis has been prepared in view of a growing concern over problems in obtaining refinery sites and an apparent lack of adequate new construction plans to meet future crude processing requirements. The Refining Division of the Office of Oil and Gas has prepared this study.

John Ricca, Acting Director
Office of Oil and Gas
August 1971

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Tables

Table I - Petroleum Refining Capacity and Actual Crude Runs - MB/CD

Table II - Petroleum Refinery Expansions - MB/CD

Appendix

Refinery Locations
Refinery Districts

U.S. PETROLEUM REFINING CAPACITY AND UTILIZATION

Object

To analyze past and present trends in U.S. petroleum refining capacity in relation to crude runs and by districts. To review planned new construction projects in relation to actual needs, also by districts.

Summary

After some eight or nine years of relatively low service factor, petroleum refineries are now in a period of higher utilization or "tightness" of available spare capacity. Similar periods have occurred in the past, the last one being in 1955-1957. However, there is one development of significance and concern associated with the current situation. There is a definite deficiency in both planned expansions and new refineries. For example, in 1973 not one single new facility of appreciable size is expected to come on stream. Any refinery project for a significant increase in crude capacity by 1973 would already be in engineering, with construction contracts let and attendant publicity in trade journals.

When considering future petroleum product requirements and assuming all known firm plant expansions to be completed on schedule, it is apparent that by 1975 all U.S. refineries would be operating constantly at full design capacity, - a very unlikely and impractical situation. To offset this situation, new firm projects totalling 1,550 M b/d capacity (for 1974 completion) would have to become established in the next few months. This amount of capacity is about double that installed in some of the record previous construction years. Even if this capacity is installed utilization would still be high, as it is at the present time.

Another significant factor is the progressively worsening position of refining on the East Coast in terms of supplying the area requirements.

The lack of firm new refinery projects may be attributed to a combination of reasons including opposition by conservationists, economic factors and uncertainty of future import policies. The short term answer will almost certainly be to increase product imports. This will be necessary even if a crash program for new capacity were to begin immediately.

Area Analyses

District I (Me., Vt., N.H., Mass., R.I., Conn., N.Y., N.J., Pa., Del., Md., Wash. D.C., N.C., S.C., Ga., Fla., Va., W.Va.)

No significant change in refining capacity or crude runs has occurred in this district over the past several years. In 1959 there were 38 operating refineries. There are now only 30. Expansions of existing plants have offset capacity loss due to shutdowns. The district's refineries only supply about 24% of the area's petroleum product requirements. District III is the largest single supplier by water and pipeline. However, imports are the fastest growing source of supply and might become the principal supplier of petroleum products to the district in as little as three years. These trends may be noted in Figure 7.

To become self-sufficient in petroleum refineries current capacity would have to be quadrupled by adding almost 5 million barrels per day of capacity. Just to back out imported products alone would require about 2 million barrels per day of new capacity.

For the past two or three years a number of companies have been seeking to locate refineries in District I without success primarily due to opposition from conservationists. These include Shell, Occidental, Guardian, Fuel Desulfurization Inc., and Atlantic Refinery Associates Inc. Aside from one or two small inland plants only two known new projects are successfully proceeding. One is the 70 M b/d Georgia-Florida Oil Company plant at Brunswick, Georgia due on stream in 1972 and the Supermarine refinery at Hoboken, New Jersey due for 1974 completion.

In view of the enormity of any program to restore District I to any significant level of refining self-sufficiency and considering the aforementioned factors regarding siting problems, it appears that District I will remain dependent on outside supply of products for many years. This will be true even if import policy changes are made, although such changes would at least arrest and directionally correct the deteriorating situation.

<u>District II</u> (N.D., S.D., Minn., Nebr., Iowa, Kans., Okla., Mo., Wisc., Ill., Mich., Ind., Ohio, Ky., Tenn.)

District II refineries supply about 83% of the area's requirements for petroleum products. Since imports are very small, most of the balance is supplied from District III by pipeline and the Mississippi River.

Since there are no firm projects scheduled for this area after 1972, refining capacity will be very tight. Presumably the supply could come from increased shipments from District III which in turn would limit supply to District I thus forcing higher product imports into the East Coast.

District III (Ala., Miss., La., Ark., Texas, N.M.)

Refinery capacity in District III has grown more rapidly than in the balance of the U.S., particularly in recent years. Construction has been motivated by closeness to producing fields, abundant low cost plant fuel gas and apparently less problems in respect to refinery siting than other areas.

Refinery output is considerably greater than the area's requirement and most of it is exported to Districts I and II. Assuming that this situation will continue in the near future, new construction appears adequate through 1972. However, as in other districts, no firm projects are known for this district after 1972. In fact there are no known tentative or uncertain projects after that date for new crude capacity.

District IV (Mont., Idaho, Wyo., Utah, Colo.)

This district is 100% dependent on its refinery capacity for petroleum product supply. Of the total refinery output 82% is consumed in the area and the remainder represents net pipeline movements into neighboring districts. As in most other areas, no new capacity plans are known beyond 1972.

District V (Wash., Oreg., Nev., Ariz., Calif., Alaska, Hawaii)

District V refineries supply 88% of the area's requirement for petroleum products. Five percent comes from imports and 7% by water and pipeline from other districts (net movement). Present and projected refinery capacity appears to be satisfactory for two or three years ahead but, as elsewhere, there are no firm projects from 1973 onward.

New Construction Plans

New construction is summarized in Table II. A large number of the items represent debottle-necking or expansion of existing facilities. In 1971 only two or three strictly "new" refineries will come on stream and these are all in District V.

In 1972 some new refineries will come on stream in all Districts except District IV and 1972 will be close to a normal construction year.

Although added capacity can be obtained by expanding existing facilities there are limitations as to how far one can go in this type of construction. While it would appear that there is less of a problem with conservationists by going this route, even expansions are now being resisted. An example is the Puget Sound area where oil refinery and terminal expansions are being opposed.

The year 1973 is essentially devoid of any new capacity. Although there have been some other years in U.S. refining history when no net increases in capacity occurred, these lapses were primarily due to economic reasons. Opposition by conservationists has contributed in a large measure to the lack of new construction in 1973.

The last part of Table II contains a listing of uncertain projects. All of those shown for District I have been opposed by environmentalists. The Occidental project is the only one which has also been opposed for other reasons besides opposition from conservationists.

In this last portion the projects listed in other districts are classified as "uncertain" only because they are still in very early stages of planning and cannot yet be called "firm" projects.

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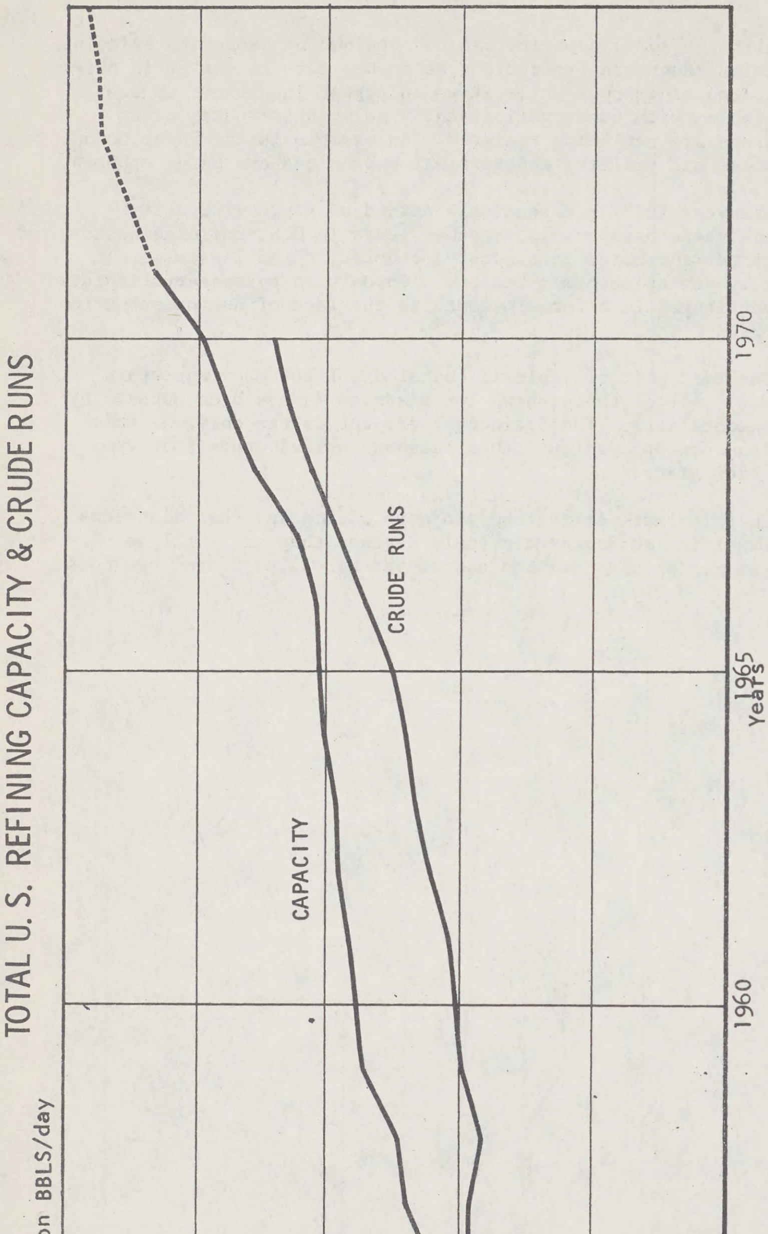

TOTAL U. S. REFINING CAPACITY & CRUDE RUNS
Million BBLS/day
14
12
10
8
6
CAPACITY
CRUDE RUNS
1960
1965
1970
Years

Figure 1

DISTRICT I
REFINING CAPACITY & CRUDE RUNS

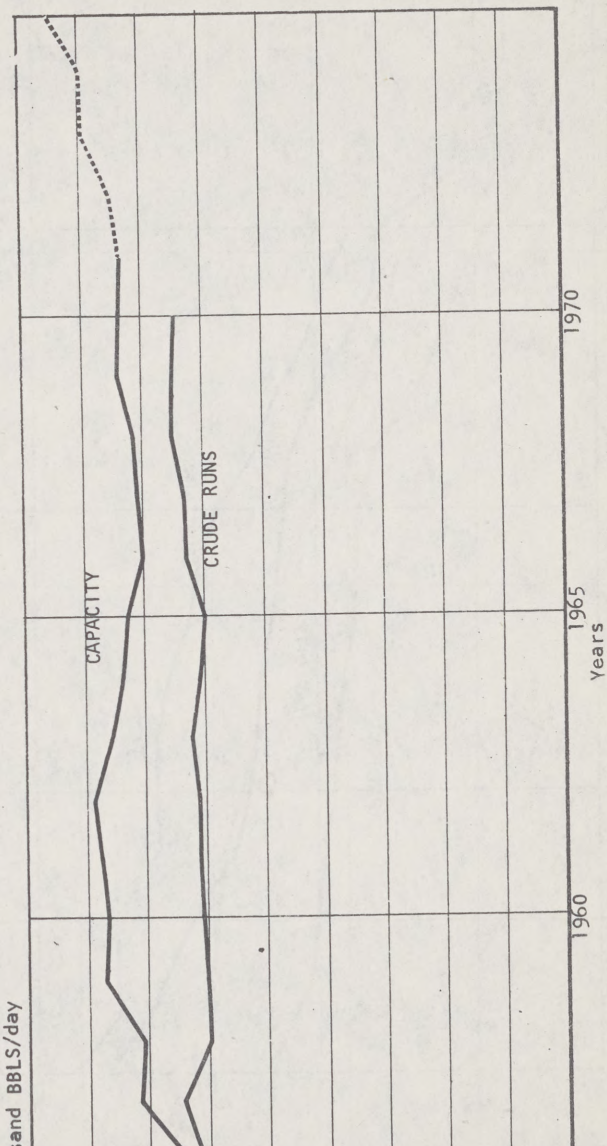


Figure 2

DISTRICT II
REFINING CAPACITY & CRUDE RUNS

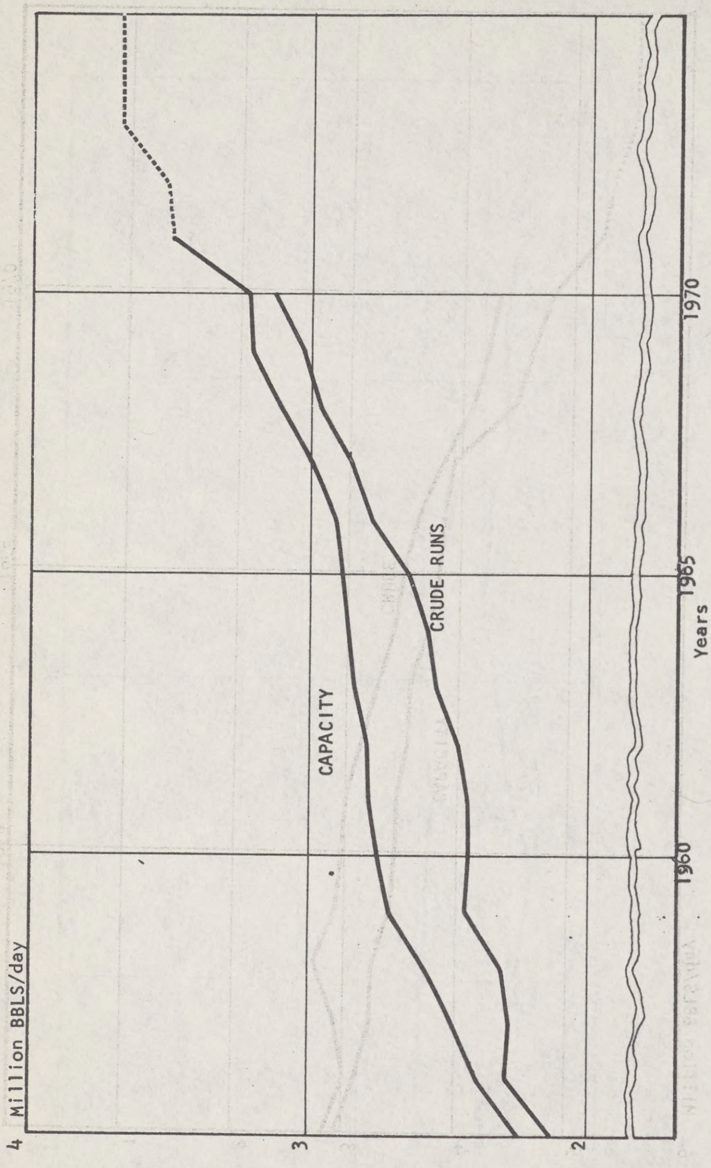


Figure 3

DISTRICT III
REFINING CAPACITY & CRUDE RUNS

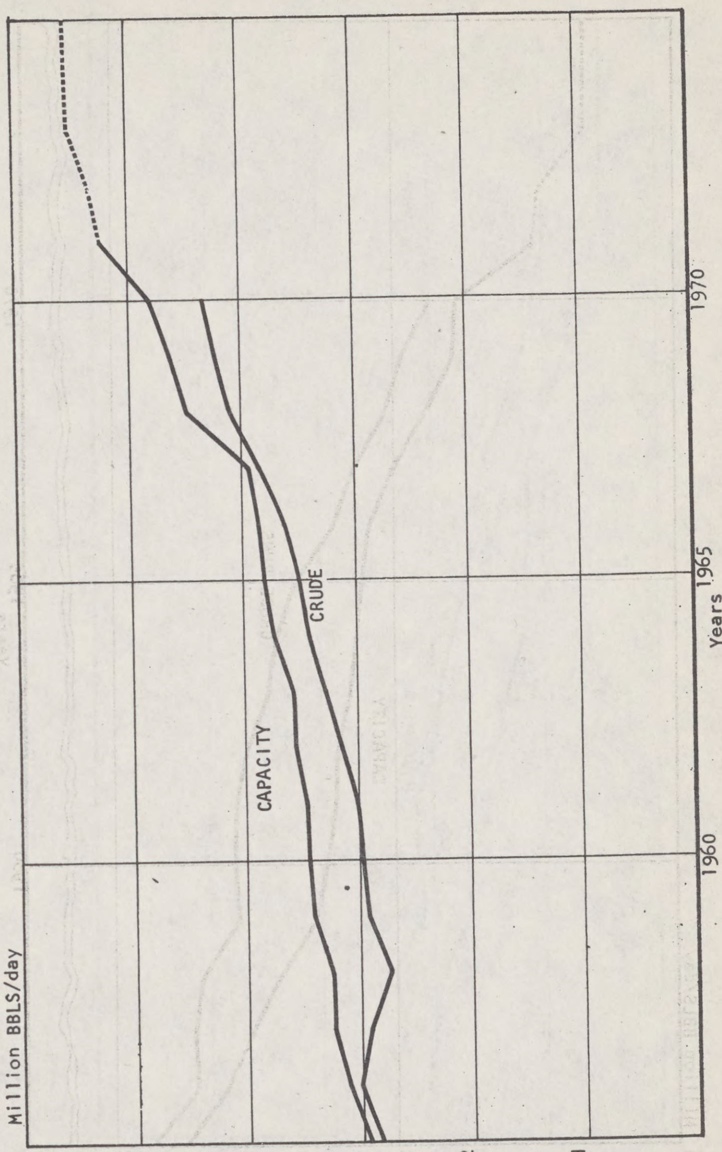


Figure 4

DISTRICT IV
REFINING CAPACITY & CRUDE RUNS

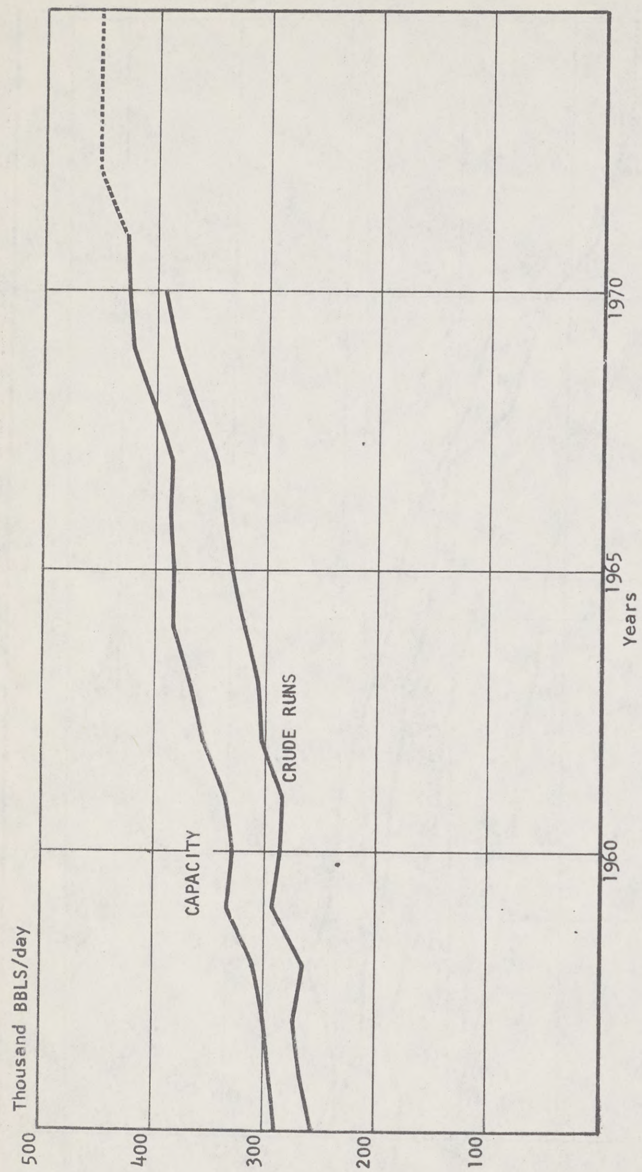


Figure 5

DISTRICT V
REFINING CAPACITY & CRUDE RUNS

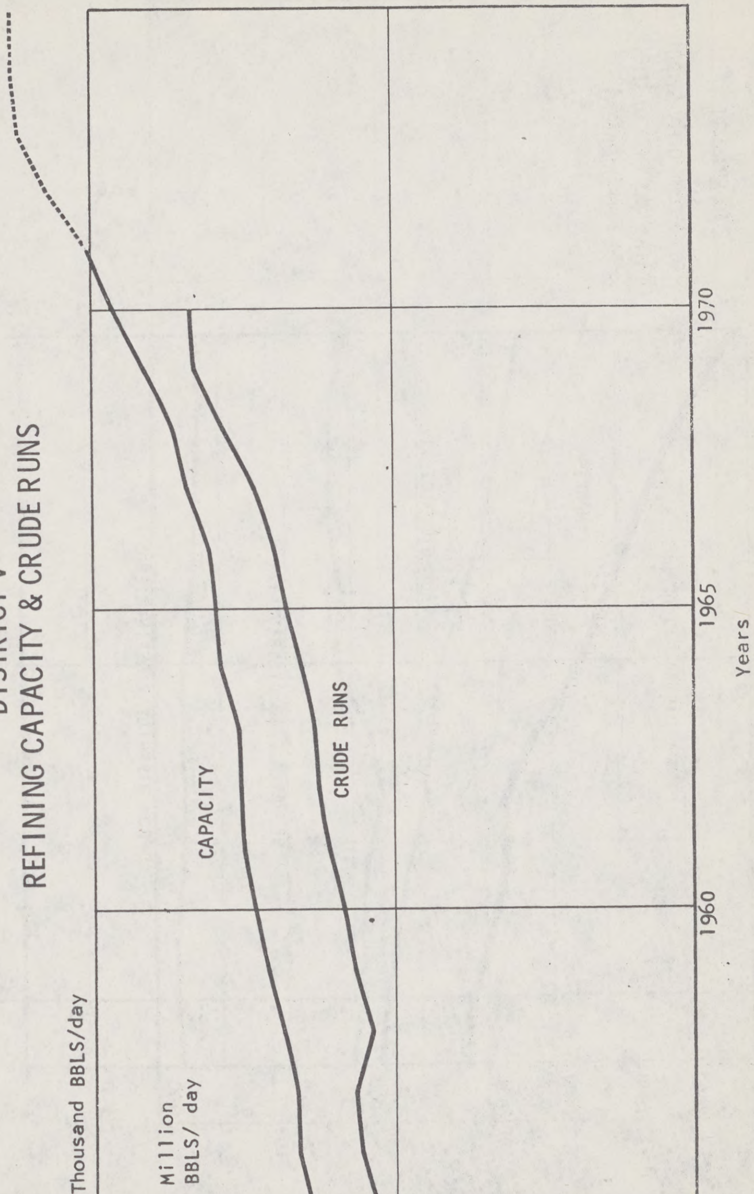
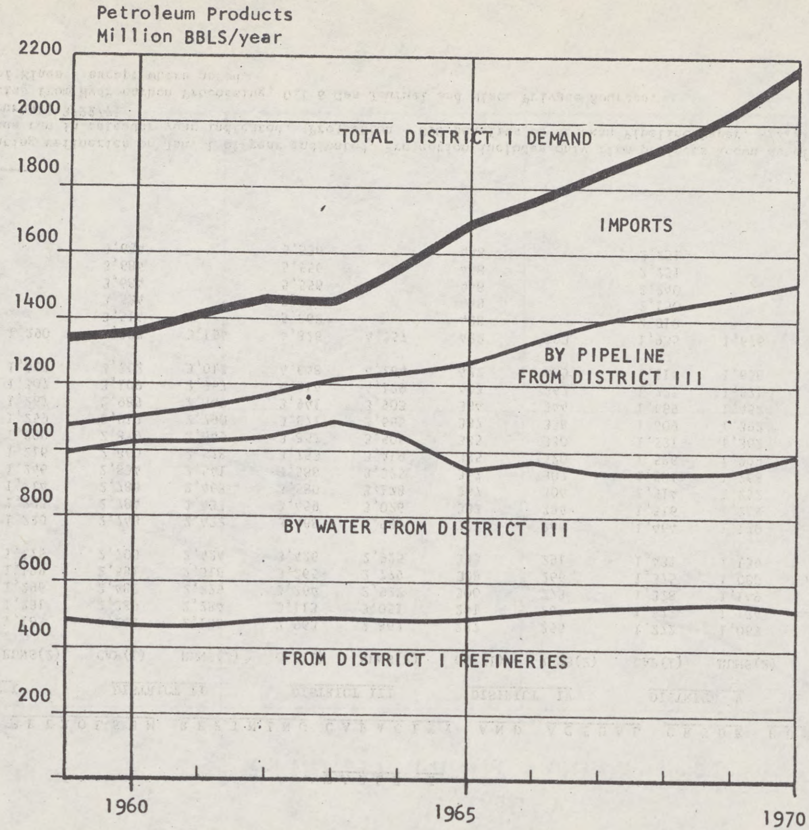


Figure 5



DISTRICT I

Refineries only supply a minor portion of their area requirement

Figure 7

TABLE I

PETROLEUM REFINING CAPACITY AND ACTUAL CRUDE RUNS - MB/CD

	DISTRICT I		DISTRICT II		DISTRICT III		DISTRICT IV		DISTRICT V		TOTAL U. S.		
	CAP(1)	RUNS(2)	CAP(1)	RUNS(2)	CAP(1)	RUNS(2)	CAP(1)	RUNS(2)	CAP(1)	RUNS(2)	CAPACITY(1)	RUNS(2)	PERCENT
1955	1,305	1,163	2,242	2,136	2,963	2,863	287	255	1,272	1,063	8,069	7,480	92.6
1956	1,266	1,231	2,389	2,284	3,113	3,051	291	269	1,322	1,124	8,381	7,959	95.0
1957	1,435	1,296	2,482	2,279	3,264	2,922	300	273	1,328	1,149	8,809	7,919	89.9
1958	1,411	1,199	2,581	2,318	3,265	2,779	308	266	1,375	1,080	8,940	7,642	85.3
1959	1,556	1,215	2,705	2,424	3,426	2,925	333	291	1,431	1,139	9,451	7,994	84.6
1960	1,536	1,220	2,748	2,422	3,468	2,989	327	286	1,464	1,170	9,543	8,067	84.5
1961	1,538	1,223	2,784	2,433	3,459	3,026	333	284	1,516	1,219	9,630	8,184	84.8
1962	1,578	1,214	2,783	2,463	3,580	3,178	357	304	1,514	1,252	9,812	8,410	85.8
1963	1,507	1,246	2,834	2,541	3,588	3,325	362	307	1,524	1,268	9,815	8,687	88.4
1964	1,479	1,216	2,860	2,578	3,753	3,419	385	320	1,586	1,299	10,063	8,807	87.5
1965	1,449	1,200	2,879	2,645	3,857	3,506	385	330	1,591	1,362	10,161	9,043	89.0
1966	1,391	1,259	2,913	2,790	3,871	3,665	387	338	1,609	1,392	10,171	9,444	93.0
1967	1,409	1,267	2,989	2,849	3,941	3,903	384	344	1,689	1,452	10,412	9,815	94.1
1968	1,423	1,307	3,109	2,967	4,514	4,129	403	367	1,725	1,571	11,173	10,312	92.5
1969	1,480	1,309	3,212	3,013	4,648	4,264	422	385	1,814	1,658	11,576	10,629	92.0
1970	1,473	1,290	3,227	3,154	4,826	4,357	422	393	1,935	1,676	11,882	10,870	92.0
1971(3)	1,467		3,514		5,262		428		2,010		12,681	11,470	90.6
1972(Proj)	1,505		3,524		5,366		448		2,150		12,996	12,070	93.0
1973(Proj)	1,595		3,684		5,556		448		2,240		13,496	12,670	93.9
1974(Proj)	1,595		3,684		5,556		448		2,251		13,507	13,270	98.3
1975(Proj)	1,695		3,684		5,556		448		2,251		13,607	13,870	100.0 +

(1) Capacity of operating refineries on Jan. 1 of year indicated. Projection includes only firm projects known as of 7/30/71.
(2) Total bbls of crude run in calendar year indicated. Projection - OOG Benefits of Alaskan Pipeline Paper, 4/2/71.
(3) From Oil & Gas Journal, 3/22/71.
Projected capacities from Hydrocarbon Processing, Oil & Gas Journal and Misc. Private Sources.
Source: Bureau of Mines - except where noted.

OOG/7-21-71
Peer

TABLE II

PETROLEUM REFINERY EXPANSIONS - CRUDE DISTILLATION - M B/D

Company/Location Firm Projects	I	II	III	IV	V	TOTAL
1971						
Chevron (Baltimore)	3.6					
Humble (Linden)	63.0					
Humble (Bayonne)	(33.0)					
Kendall (Bradford, Pa.)	4.0					
CRA (Scotts Bluff, Neb.)		1.5				
Bell (Ardmore, Okla.)		3.0				
Champlin (Enid, Okla.)		4.0				
Midland Coop (Cushing; Okla.)		1.5				
Conoco (Lake Charles, La.)			11.0			
Texaco (Port Arthur, Tex.)			80.0			
Caribou (Kirtland, N.M.)			1.0			
Champlin (Corpus Christie)			3.0			
Diamond Shamrock (Sunray)			7.5			
Southland (Sandersville, Miss.)			1.1			
Husky (Cheyenne)				6.0		
Caribou (Woods Cross, Utah)				1.0		
American (Salt Lake City)				13.0		
Douglas (Paramount, Calif.)					10.5	
Arco (Bellingham, Wash.)					100.0	
Hawaiian Ind. Ref. (OAHU)					29.5	
Lunday Thagard (S. Gate)					4.0	
TOTAL:	37.6	10.0	103.6	20.0	144.0	315.2

TABLE II (Continued)

PETROLEUM REFINERY EXPANSIONS - CRUDE DISTILLATION - M B/D

Company/Location Firm Projects	I	II	III	IV	V	TOTAL
1972						
Georgia-Fla. Oil & Ref (Brunswick)	70.0					
Witco (Bradford, Pa.)	10.0					
Quaker State (Hancock Co. W. Va.)	10.0					
Mobil (Joliet, Ill.)		160.0				
Gulf (Alliance Ref, La.)			155.0			
Murphy (Mereaux, La.)			35.0			
Arco (Fairbanks, Alaska)					10.0	
Dillingham (Barbers Pt., Haw)					50.0	
TOTAL:	90.0	160.0	190.0	0	60.0	500.0
1973						
Mobil (Ferndale, Wash.)	-	-	-	-	11.0	11.0
1974						
Supermarine (Hoboken)	100.0	-	-	-	-	100.0

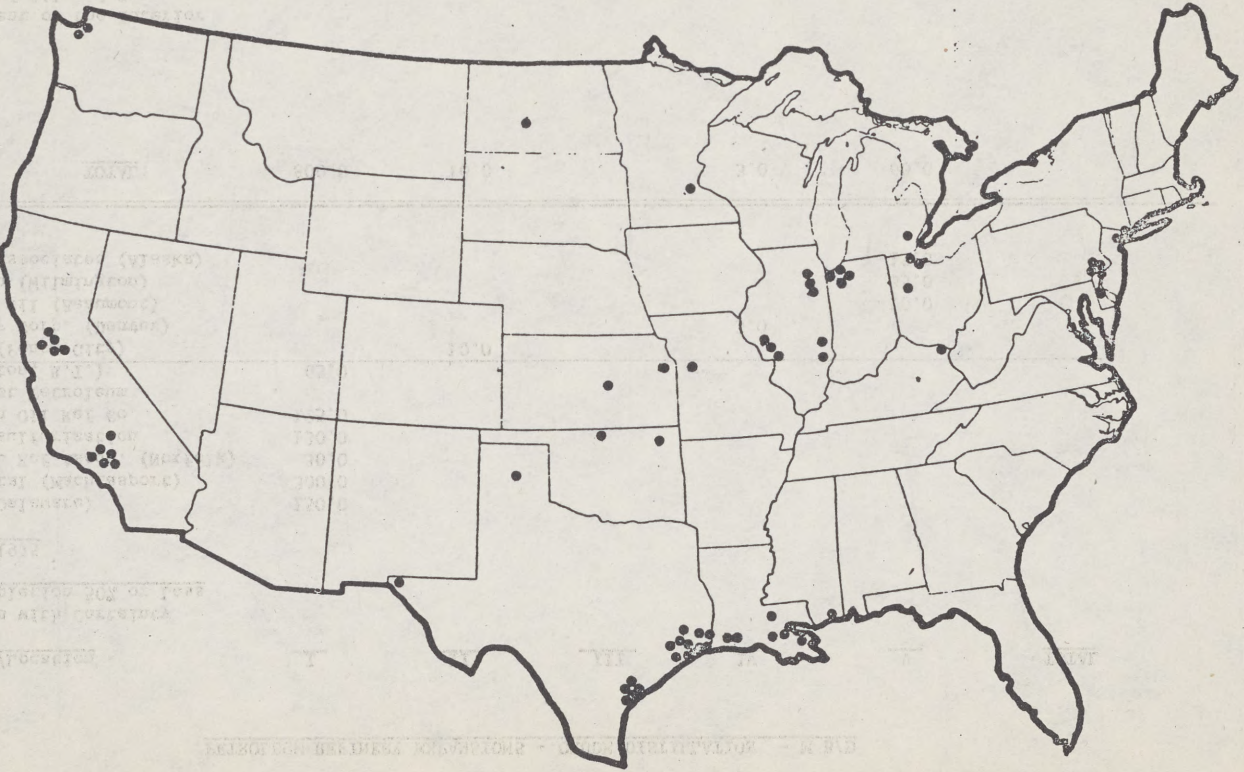
TABLE II (continued)

PETROLEUM REFINERY EXPANSIONS - CRUDE DISTILLATION - M B/D

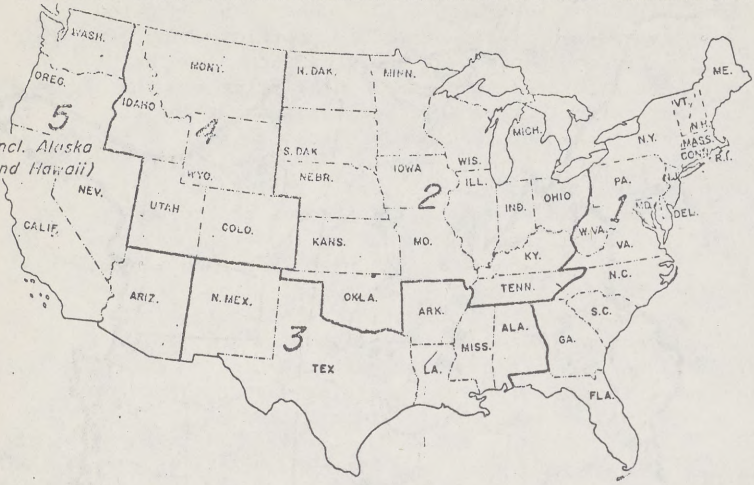
Company/Location	I	II	III	IV	V	TOTAL
Projects with Certainty of Completion 50% or Less						
1973 - 1975						
Shell (Delaware)	150.0					
Occidental (Machiasport)	300.0					
Atlantic Ref Assoc. (Norfolk)	30.0					
Fuel Desulfurization	130.0					
Guardian Oil Ref Co.	125.0					
Northeast Petroleum (Tiverton, R.I.)	65.0					
Conoco (Ponca City)		10.0				
Refinery Corp. (Denver)				3.0		
Clinton Oil (Beaumont)					10.0	
Champlin (Wilmington)					35.0	
Energy Associates (Alaska)					15.0	
TOTAL:	800.0	10.0		3.0	60.0	

Department of the Interior
Office of Oil and Gas
August 1971

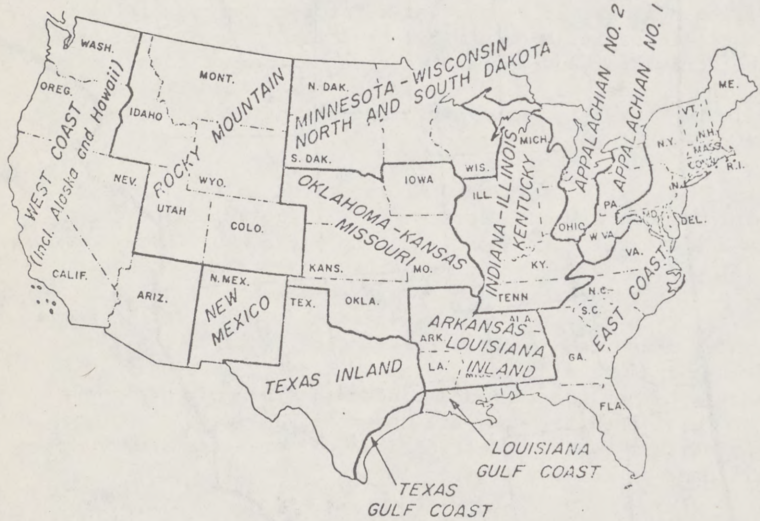
The Location of Refineries Processing 50,000 Barrels of Crude Oil Per Day or More



PETROLEUM ADMINISTRATION FOR DEFENSE (PAD) DISTRICTS



BUREAU OF MINES REFINING DISTRICTS



Trend Analysis System

The two tabulations submitted by Dr. Osborn are compiled from a system of individual commodity profiles which, in turn, result from a continuous study conducted by the Bureau of Mines for the purpose of identifying how the national interest might be affected by apparent changes in emerging mineral supply-demand relationships.

Although the statements are frequently revised to reflect any significant changes in supply patterns or end-use applications, a comprehensive updating is performed annually as current critical data relating to world production and consumption become available. Accordingly, the statements have now been revised to reflect the relationships that became apparent at the close of 1969. Similarly all analyses of probable future patterns have been reestimated in light of current information and the emerging factors that would now seem to influence future relationships.

Important changes in format have been adopted in this revision in response to aspects of mineral supply-demand relationships that attracted increased attention during the past year. Among these are a more detailed assessment of world resources available at various prices, an accounting of production capacities on a geographic basis, and detailed treatment of possible changes in the individual end-use applications of commodities. Otherwise, the topics, to which the statements are addressed, conform closely to those that have attracted attention continuously since the study was initiated in 1967.

As previously, the statements are directed to the individual mineral forming elements, common fossil fuels, and certain gases and mineral forms that have, or might have, some commercial significance. In many instances the subjects are addressed in terms of their elemental content in preference to the mineral forms in which they are commonly priced, traded, and in some instances consumed, in current marketing patterns. Although the resulting units are not commonly used in statistical presentations or the familiar discussions of current supply-demand relationships, they are essential in speculating upon supply patterns where non-traditional mineral forms may become significant as primary sources in the future.

Certain data are obliterated on some copies of the statements because the manner in which that information became available to the Bureau of Mines does not permit general disclosure.

The following describes the content and scope of the series of basic compilations and analyses that are seen as necessary to provide an initial means of assembling meaningful findings, drawing conclusions, and formulating appropriate recommendations:

SUMMARY

Where the products of the "background" and "outlook" documentation are reduced to the essential points that attract attention in defining problems that may merit national attention in emerging supply-demand relationships.

BACKGROUND

Supply-Demand Relationship

Based upon the latest year for which absolute production and distribution are available, the "present" domestic supply-demand relationship is defined and diagramed. The sources of world production are identified. The portions of this production flowing to and within the U.S. is shown together with all components of domestic supply during that year. Quantities exported or retained in year-end stocks is shown. The end-uses to which supplies were committed (demand) are described and quantified.

Similar balances for each of the ten preceding years are furnished in tabular form to display the range of changes in such relationships.

Apparent Reserves

Wherein commercial reserves are described by countries and by continent, in terms of potential availability at various price levels expressed in terms of current constant dollars per unit of the contained mineral substance that is being appraised.

Industry Pattern

In which the structures of the producing industries at home and abroad are described. The degree of vertical or horizontal integration, major elements of corporate geography, the nationalized increments of foreign supply, etc., are summarized.

Production and Capacity

Essentially, this is a tabulation of existing installed (rated) world production capacity compared to production in the latest statistical year. An attempt is made to separately define mine, smelter and refinery capacity (or other appropriate plant component, dependent upon the commodity). Further, installed capacities are indentified by continent and country.

Similarly, changes in capacity, indicated by ongoing developments or corporate announcement of intentions, is compiled to permit assessment of imminent changes in production capacities. An assessment of foreseeable changes in world (and country) productive capacity during the next decade (or as far as valid data permit) are assembled independent of any forecasted requirements estimate or market outlook.

Consumption Pattern

This section enlarges upon the end-use pattern identified in the initial identification of "supply-demand" relationships. The flow of materials through intermittent forms (like alloys) to ultimate end-uses (like automobiles) is summarized. The recycling of scrap, where significant, is diagramed.

Byproductions and Coproducts

An exact quantitative assessment is made of the materials issuing through fixed mineralogical relationships with other commodities or where the quantity of supply is a direct function of plant capacity, rather than resource availability (like hafnium-zirconium).

Economic Factors

The time-price relationships (converted to current constant dollars) is developed for the past 20 years. The pertinent tax, tariff, and related factors important to the commodity is defined. The effect of Governmental policies (like leasing) or strategic considerations like stockpiling (or disposal) are included. Investment factors are presented where pertinent (like investment required to affect a ton/year of production capacity).

Technology

This is essentially a digest of the current state of the art--in mining, processing, using and disposing of mineral or mineral-based substances.

Operating Factors

The materials, energy and other substances consumed in the production of a commodity (input-output) are appraised. Recovery factors (losses) in the extraction, processing and using stages are described with the attendant environmental impact and conservation implications clearly defined. Social and occupational factors that bear upon operating practices are itemized. Manpower and productivity factors are assessed.

OUTLOOK

Demand

Forecasts of U.S. and rest-of-the-world requirements in 2000 (and cumulatively) are compiled based upon a summation of separate analyses of probable changes in consumption rates in each end-use sector, and reflecting probable changes in the relationship of primary and secondary components of supply (like the effect on primary and secondary relationships in lead when the element is removed from gasoline). For the U.S., the demand forecast for each end-use increment in 2000 are expressed in terms of high and low expectations based on described contingencies, and a most "probable" demand estimate is made.

To appraise primary requirements specifically, the U.S. demand for primary materials is compared to domestic primary production during the 20 years preceding the latest year for which absolute supply/demand data are available, and this relationship in 2000 will be described in terms of historical trends and foreseeable changes in domestic capabilities.

Supply

The "demand" estimates are related to "apparent reserves" and to the "economic factors" to define the material, environmental and social costs likely to be involved in meeting projected requirements.

Possible Changes in Technology

The effect of ongoing industrial research and processing trends (like advancements in pre-reduced iron technology and chemical copper processes) are related to demand estimates. Problems posing technologic challenges in supply, processing, utilization and disposal are defined.

Possible Changes in Supply-Demand Relationships

All the foregoing is assessed in terms of foreseeable changes in the geography of supply, trends toward substitution of materials, changes in by-product and coproduct relationships and departures from traditional use patterns.

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Many different summations may be drawn from this system of continuous individual commodity analyses. The tabulations presented by Dr. Osborn are drawn from only one section of the foregoing outline entitled "Possible Changes in Supply-Demand Relationships" where U.S. primary mineral supply-demand relationships that existed in 1969 are compared to those that are anticipated for 2000.

Specifically, the tabulations show the quantity and value of primary minerals that would have to be derived from domestic sources in 2000, if (1) the present (1969) production to demand ratio is maintained, and (2) if production trends of the past 20 years prevail. Differences between the constant ratio projections and those based on historical production trends indicate potential changes in the percentage of the U.S. demand for minerals that may be met from domestic sources.

In 1969, the U.S. demand for primary minerals totaled approximately $37.4 billion. On the basis of 1969 constant dollars, the demand is expected to increase about 4 times to $150 billion in 2000.

It is apparent from the tabulations that, by 2000, domestic production will supply substantially less of the demand for primary minerals than it does at present. For example, to maintain the present production to demand ratio in 2000 a domestic primary mineral production of $109 billion would be required. However, based on historical production trends of the past 20 years a deficit of almost $46 billion is indicated for 2000.

The following current profile on copper illustrates the format, content and scope of the series of studies of each significant commodity from which the tabulations of forecasts are compiled:

COPPER

Installed productive capacity and the level of technologic development governs the supply of copper and, assuming the latter will be as energetically pursued and as effective as in the past, world supplies should be adequate to meet requirements projected over the next three or four decades. Although the United States leads the world in both production and consumption, the extent to which it meets its future requirement from domestic sources is likely to decrease. As one of the key commodities in this industrial economy, domestic copper production growth should be encouraged even recognizing that imports will have to supply an increased percentage of future United States demand. Cost reductions at every stage from exploration through fabrication will have to not only accommodate the continuously decreasing tenor of raw materials but permit effective competition of foreign operations. Any technologic advance that contributes to cost reduction is, in this instance, a subject for concerted attention.

- o -

Concern over emission of sulfur compounds to the atmosphere during smelting causes the most pressing immediate problem facing the domestic copper industry. New technology and large capital investments will be required to either modify existing pyrometallurgical practices or adopt new chemical-process techniques as a solution to the problem if the United States is to maintain a viable copper industry.

- o -

The domestic extraction industry also faces potentially critical land-use conflicts. Unless opposing views on surface restoration standards, waste disposal, and pollution issues are reconciled without excessive increases in operating costs, the competitive position of United States supplies will deteriorate sharply. Conflicts are inherent in the emerging programs designed to protect natural endowments, to improve the Nation's environment and insure the welfare of its growing population. Specifically, the Wilderness program and public works designed to conserve essential land and water resources will increase confrontations with the industry and will present increasingly difficult problems for reconciliation. Yet it is essential in the public interest that such issues be equitably resolved. The subject deserves the highest order of priority.

March 17, 1971

Because approximately one ton of makeup water is required per ton of ore processed in the concentrator, and with population increases and industry expansions, conflicts for sufficient water to process increasing quantities of ore can be anticipated in the Western States where much of the production is obtained. Decreased water requirements could result from research on the beneficiation step.

- o -

The supply of a host of byproducts and coproducts depends upon the rate of copper production, and the technology of processing and refining. The 1969 value of these, recovered from the domestic processing of predominately copper ores was nearly $140 million. Any innovation or technologic improvement that affects the recovery or use of the coproducts improves the overall economics of copper production, coincidental to the direct benefits to the coproduct, and thus merits attention.

- o -

Major opportunities for cost reduction are present in the initial extraction (mining) process. Attention to improvements in conventional systems as well as new approaches (like in-situ-nuclear-leaching) is demanded. Large quantities of low-grade copper-containing waste are bypassed or moved in the mining operations. Improved recovery of copper from such "waste" products of mining would effect important additions to the domestic copper supply and enhance overall production economics. Large quantities of sulfuric acid resulting from smelter pollution controls could be used in leaching to materially improve the economics of leaching copper from mine wastes. Further, large quantities of low tenor copper-containing waste are discharged from the concentrator. Such material represents a large copper loss that should be recovered, possibly by leaching.

Improved recovery of copper from the waste products of milling and refining would effect important additions to the domestic copper supply. By the same token, the ultimate disposal of the waste products from these operations is, as in the case of mining, a growing problem that promises increased processing costs if new concepts or practices are not developed.

- o -

Except for a few dissipative uses, much of the copper used adds to a "reserve" that is ultimately recoverable. At present this copper scrap supplies about a fifth of domestic demand for refined copper. From any standpoint--conservation, supply, or economics--improvements in the salvaging and processing systems for recovering and recycling secondary metal (and its coproducts) merit immediate and intensive investigation.

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The national stockpile for copper has been drawn down deeply below the minimum level considered necessary for national security as a result of the Government release of substantial quantities of copper from 1965 through 1967 to alleviate a critical shortage for military and civilian use.

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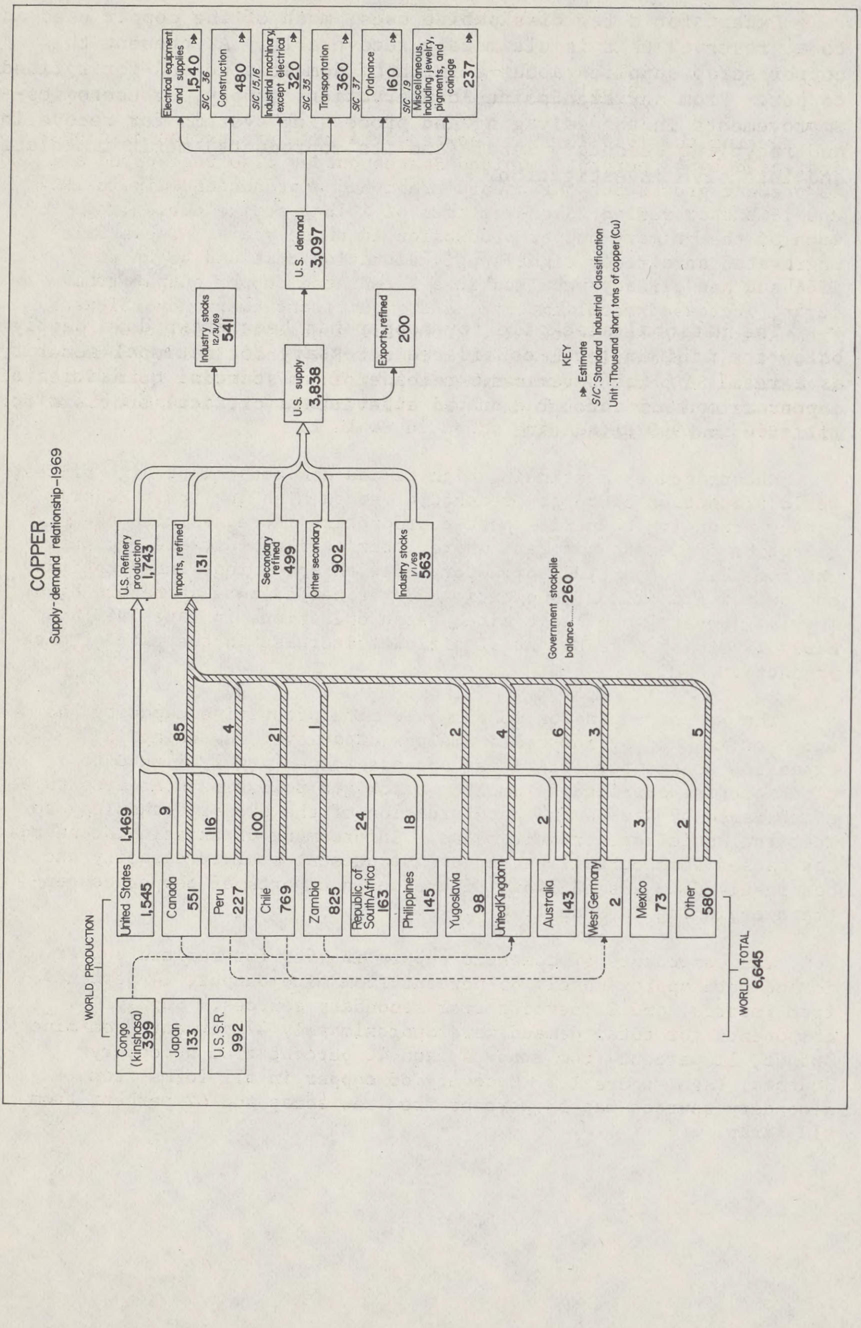
COPPER
Supply-demand relationship-1969
WORLD PRODUCTION
Congo (Kinshasa) 399
Japan 133
U.S.S.R. 992
United States 1,545
Canada 551
Peru 227
Chile 769
Zambia 825
Republic of South Africa 163
Philippines 145
Yugoslavia 98
United Kingdom
Australia 143
West Germany 2
Mexico 73
Other 580
WORLD TOTAL 6,645
1,469
9
116
100
24
18
2
3
2
85
4
21
1
2
4
6
3
5
U.S. Refinery production 1,743
Imports, refined 131
Secondary refined 499
Other secondary 902
Industry stocks 1/1/69 563
Government stockpile balance..... 260
U.S. supply 3,838
Industry stocks 12/31/69 541
Exports, refined 200
U.S. demand 3,097
SIC 36 Electrical equipment and supplies 1,540
SIC 15,16 Construction 480
SIC 35 Industrial machinery, except electrical 320
SIC 37 Transportation 360
SIC 19 Ordnance 160
Miscellaneous, including jewelry, pigments, and coinage 237
KEY
Estimate
SIC: Standard Industrial Classification
Unit: Thousand short tons of copper (Cu)

BACKGROUND

Supply-Demand Relationship

During the 1960 to 1969 decade world mine production of copper increased by 43 percent. United States output also registered a 43 percent growth but the upward trend had a pronounced dip in 1967 and 1968 that reflected the effects of a long strike curtailing much of the primary copper production in those years. The strike aggravated an already tight supply situation that had begun in 1964 and had already resulted in a stimulated copper output from scrap, increased metal imports, and significant emergency releases from the Government stockpile. Domestic consumption followed closely the production trend with industrial demand for the decade increasing 36 percent for refined copper and 57 percent including all secondary consumption. The annual supply-demand relationships during the 1960 to 1969 decade are shown in Table 1.

Encouraged by continuing high demand and consequent high prices, world production of copper reached a record high in 1969. Major copper producing countries posted production increases with the exception of Canada and Peru where labor strikes curtailed output. The domestic copper industry operated with only minor interruptions and output from mines, smelters, and refineries were at record high levels. Several new large mines began operations in late 1969 and early 1970 with a resultant significant increase in the rate of mine production.

The recent expansion of domestic mine productive capacity has not been matched by increased smelter capacity. The delay in expansion of smelter facilities appears to be largely linked to uncertainties surrounding smelter stack gas pollution standards to be established by States and determination of the proper technology to meet the anticipated requirements. Enforcement of existing standards has caused some curtailment in use of present smelter capacity and has resulted in a significant increase in exports of copper concentrate beginning in June 1970.

The components of domestic supply in 1969 for refined copper demand were approximately 65 percent from mine output, 14 percent from imports, and 21 percent from secondary sources. Supply components for total demand were approximately 47 percent from mine output, 11 percent from imports, and 42 percent from secondary sources. (See Figure 1.) Recovery of copper in all forms from secondary sources was 58 percent from new scrap and 42 percent from old scrap.

TABLE 1. - Copper Supply-Demand Relationships, 1960-1964
(Thousand short tons)

	1960	1961	1962	1963	1964
World Production - Primary					
Mine Production:					
United States	1,080	1,165	1,228	1,213	1,247
Rest of World	3,560	3,685	3,862	3,987	4,050
Total	4,640	4,850	5,090	5,200	5,297
Components of U.S. Supply					
Domestic mines	1,121	1,181	1,214	1,219	1,259
Secondary materials (refined)	291	282	290	302	351
Government stockpile releases	---	5	8	11	27
Imports (refined)	143	67	99	119	140
Imports (ores, blister, etc.)	398	369	398	377	396
Industry stocks, January 1	433	554	510	537	527
Other secondary (alloys and chemicals)	579	567	632	672	742
Total U.S. Supply	2,965	3,025	3,151	3,237	3,442
Distribution of U.S. Supply					
Industry stocks, Dec. 31	554	510	537	527	467
Exports (refined)	434	429	337	311	316
Industrial demand	1,977	2,086	2,277	2,399	2,659
U.S. Total Demand Pattern					
Electrical	850	897	888	887	904
Construction	396	438	455	480	559
Machinery, etc.	297	292	387	384	452
Transportation	257	271	319	336	372
Ordnance	79	83	114	192	266
Miscellaneous	98	105	114	120	106
Total	1,977	2,086	2,277	2,399	2,659
U.S. Primary demand (Industrial demand less secondary (refined) and other secondary)	1,107	1,237	1,355	1,425	1,566
U.S. Demand for refined copper (Industrial demand less other secondary)	1,398	1,519	1,645	1,727	1,917

TABLE 1. - Copper Supply-Demand Relationships, 1965-1969 (Cont.)
(Thousand short tons)

	1965	1966	1967	1968	1969
World Production - Primary					
Mine Production:					
United States	1,352	1,429	954	1,205	1,545
Rest of World	4,197	4,371	4,610	4,794	5,100
Total	5,549	5,800	5,564	5,999	6,645
Components of U.S. Supply					
Domestic mines	1,336	1,353	847	1,161	1,469
Secondary materials (refined)	445	491	407	417	499
Government stockpile releases	120	400	149	---	---
Imports (refined)	137	164	331	400	131
Imports (ores, blister, etc.)	376	358	286	276	274
Industry stocks, January 1	467	498	602	507	563
Other secondary (alloys and chemicals)	808	886	836	854	902
Total U.S. Supply	3,689	4,150	3,458	3,615	3,838
Distribution of U.S. Supply					
Industry stocks, Dec. 31	498	602	507	563	541
Exports (refined)	325	273	159	241	200
Industrial demand	2,866	3,275	2,792	2,811	3,097
U.S. Total Demand Pattern					
Electrical	946	1,113	1,200	1,375	1,540
Construction	630	720	530	445	480
Machinery, etc.	459	589	419	280	320
Transportation	401	426	307	335	360
Ordnance	287	262	195	172	160
Miscellaneous	143	165	141	204	237
Total	2,866	3,275	2,792	2,811	3,097
U.S. Primary demand (Industrial demand less secondary (refined) and other secondary)	1,613	1,898	1,549	1,540	1,696
U.S. Demand for refined copper (Industrial demand less other secondary)	2,058	2,389	1,956	1,957	2,195

Apparent Reserves

Domestic reserves of copper in ore, based largely on a Bureau of Mines 1964 survey, are estimated to be 81 million tons at the average 1969 price. Arizona, Montana, Utah, New Mexico, and Michigan were the leading States in measured and indicated reserves, with Michigan having the largest inferred reserves. The five States accounted for over 90 percent of the total reserves, 95 percent of which are in copper ores and the remainder in mixed or complex base metal ores. Tenor of the copper ores is estimated to average 0.86 percent copper.

Reserves of copper in the rest of the world are estimated to be 215 million tons at 1969 prices. The leading producing countries of Chile, the U.S.S.R., Zambia, Peru, the Congo (Kinshasa), and Canada account for 78 percent of this total. Remaining reserves are divided among many other countries including Australia, China, Finland, Iran, Japan, Mexico, the Philippines, Poland, Republic of South Africa, Sweden, and Yugoslavia.

An assessment of world copper resources recoverable at various prices is shown in Table 2.

A large in-use resource of copper in the form of scrap has accumulated and is growing in the highly industrialized countries. The copper-in-use-pool resource has been estimated to be 40 million tons for the United States, 40 million tons for Europe, and 10 million tons for all other countries.

Industry Pattern

The United States has been the leading copper-producing country in the world since 1883, except for 1934 when economic conditions adversely affected domestic production. Other principal copper-producing countries, in ranked order, are the U.S.S.R., Zambia, Chile, Canada, and the Congo (Kinshasa).

Most of the copper mined in the United States (90 percent in 1969) is produced in Arizona, Montana, Nevada, New Mexico, and Utah, and virtually all the remainder is obtained from Michigan, Missouri, and Tennessee. Most of Chile's output comes from three large mines and the remainder comes from a number of small-and-medium-size mines. Production in Peru is derived principally from two mines. Output in the Congo (Kinshasa) comes from properties operated by one company and copper is produced in Zambia from six large mines. Ontario and Quebec combined produced approximately 78 percent of Canada's output but British Columbia with 15 percent of the total has been increasing in importance in recent years. Production from the U.S.S.R. comes from widely separated areas.

TABLE 2. - World Assessment of Copper Resources
Recoverable at Various Prices
(Million short tons of copper)

	Price, constant 1969 dollars per pound refined copper			
	0.479 1/	0.60	0.70	0.80
North America:				
Canada----------------	10	11	14	17
United States--------	81	94	94	99
Other----------------	2	3	3	3
Total--------------	93	108	111	119
South America:				
Chile----------------	57	62	72	83
Peru-----------------	24	26	29	32
Other----------------	1	1	1	1
Total--------------	82	89	102	116
Europe:				
U.S.S.R.-------------	38	41	46	50
Other----------------	8	10	10	12
Total--------------	46	51	56	62
Africa:				
Congo (Kinshasa)-----	19	21	24	27
Zambia---------------	29	32	36	42
Other----------------	8	9	9	10
Total--------------	56	62	69	79
Asia:				
Total--------------	15	17	19	20
Oceania:				
Total--------------	4	5	5	6
Total for World--	296	332	362	402

1/ Average 1969 domestic delivered price.

In 1969, 25 mines accounted for 94 percent of the U.S. output; the five largest produced 46 percent; and three companies accounted for a little more than half of the domestic mine production.

Virtually all copper ore continued to be treated at concentrators near the mines. Concentrates were processed at 17 smelters--eight in Arizona and one each in Utah, Michigan, Montana, Nevada, New Mexico, Tennessee, Texas, New Jersey, and Washington.

Copper smelting capacity in the United States in 1969 totaled 9.2 million tons of charge, estimated to represent about 1.8 million tons of smelter product. Four companies control nearly 80 percent of the capacity. Refinery capacity totaled 2.7 million tons of which 88 percent was electrolytic refining capacity and 12 percent was fire refining (including Lake copper) capacity.

About 60 percent of the domestic electrolytic refining capacity is accounted for by six refineries on the Atlantic Coast in New York, Carteret and Perth Amboy, N.J., and Baltimore, Md. Arizona, Missouri, Montana, Texas, Utah, and Washington each have one electrolytic refinery, which in total, accounted for the remaining 40 percent. Three Michigan plants (only one of which operated in 1969) produce Lake copper and refineries in New York, New Jersey, New Mexico, and Texas produce fire-refined copper.

The leading copper producing companies such as The Anaconda Co., Kennecott Copper Corp., and Phelps Dodge Corp. are integrated and have mining, smelting, refining, fabricating facilities, and marketing organizations. Other large producers mine and process through the smelting or refining stage and other companies mine and process their ore and ship the concentrate to custom plants for smelting and refining.

Many large domestic copper producers, through subsidiaries or stock holdings, operate or control foreign copper-producing properties in Canada, Mexico, Chile, Peru, the Republic of South Africa, and Zambia. In addition to copper and the usual byproducts, they are also major producers of aluminum, cadmium, chromium, germanium, lead, titanium, uranium, vanadium, zinc, asbestos, fluorspar, rare metals, and liquid and solid fuels.

Nationalization of U.S. interests in Chile began in 1967 when the Chilean Government took over a 51-percent interest in the El Teniente mine of the Braden Copper Co., a wholly owned subsidiary of the Kennecott Copper Corp. In 1969 an agreement was reached between The Anaconda Company and the Chilean Government whereby that country acquired 51 percent of Anaconda's Chuquicamata and El Salvador properties by 1970. Further nationalization of U.S. investments in Chile was proclaimed an objective of President Allende who was inaugurated in November 1970.

In August 1969 the Zambian Government announced that it would assume 51-percent control of the Zambian copper industry. Anglo American Corp. and Roan Selection Trust, Ltd. (RST) own and operate the major copper mines with over 80 percent of the shares of RST owned by U.S. interests.

Production and Capacity

Mine production of copper for both the U.S. and the world in 1969 was approximately 92 percent of the respective estimated capacities. This rate is probably near practical maximum limits of operation. Comparable values for percentage operation of smelter capacity was 87 percent for the U.S. and 92 percent for the world. The percentage operation of primary refinery capacity, including treatment of substantial quantities of secondary material, was indicated to be 81 percent for the U.S. and 85 percent for the world. Estimates of mine, smelter, and refinery capacities compared to production for principal producing countries are contained in Table 3.

Projected world copper mine, smelter, and refinery capacities through 1975 are shown in Table 4.

Mine production capacity for the United States is expected to increase by 25 percent from 1969 to 1975 or to a total of 2.1 million tons. Over the same period, the smelter capacities will increase 14 percent to approximately equal the 1975 mine capacity. However, smelter capacities for the intervening years of 1971 and 1972 are expected to be significantly below mine capacity. The validity of the 1969-70 assigned quantities is borne out by exports of about 70,000 tons of copper in concentrates in the last half of 1970 attributed to a shortage of smelter capacity and the inference that production had approached capacity. The annual rate of operation during the first ten months of 1970 was 1.70 million tons compared to an assigned 1.84 million tons of capacity.

A critical factor in consideration of smelter adequacy has been the actual and potential effects of air pollution regulations. The 1970 shortage of capacity appeared to be partly a curtailment of maximum operation at certain smelters to comply with existing pollution regulations, and to delays in expansion of facilities owing to uncertainties regarding resolution of the pollution problem. Indications are that existing smelters will generally be granted temporary variances to achieve compliance with new regulations. Technology to correct the deficiencies causing unacceptable levels of air pollution is expected to be developed and adopted but at a significant production cost. Some of the new facilities may use a non-air polluting wet chemical method that bypasses the conventional smelting

TABLE 3. - World Copper Capacity and Production - 1969
(Thousand short tons copper)

	Mine		Smelter		Refinery	
	Capacity	Production	Capacity	Production	Capacity	Production
North America						
Canada------------	680	551	540	451	540	451
United States-----	1,680	1,545	1,810	1,585	2,671	1/ 2,156
Other-------------	90	80	75	72	79	63
Total-----------	2,450	2,176	2,425	2,108	3,290	2,670
South America						
Chile-------------	810	769	815	727	795	494
Peru--------------	250	227	210	186	50	52
Other-------------	10	9	4	4	4	5
Total-----------	1,070	1,005	1,029	917	849	551
Europe						
U.S.S.R.----------	1,040	992	1,040	992	1,100	1,050
Other-------------	400	369	915	892	1,600	1,523
Total-----------	1,440	1,361	1,955	1,884	2,700	2,573
Africa						
Congo (Kinshasa)--	420	399	350	399	342	187
Zambia------------	855	825	825	823	684	659
Other-------------	245	245	380	187	108	86
Total-----------	1,520	1,469	1,555	1,409	1,134	932
Asia						
Total-------------	540	490	880	858	960	847
Oceania						
Total-------------	160	144	135	127	165	151
Grand Total-----	7,180	6,645	7,979	7,303	9,098	7,724

1/ Production at primary refineries consisting of 1,743 from primary material and 413 from secondary material.

TABLE 4. - Projected World Copper Capacity, 1969-1975
(Thousand short tons copper)

	1969	1970	1971	1972	1973	1974	1975
North America							
United States							
Mine	1,680	1,850	1,950	2,000	2,050	2,050	2,100
Smelter	1,810	1,840	1,860	1,870	2,000	2,030	2,070
Refinery	2,671	2,680	2,680	2,880	2,880	3,000	3,100
Other North America							
Mine	770	860	1,030	1,080	1,200	1,250	1,300
Smelter	615	620	620	620	620	650	700
Refinery	619	620	620	620	620	650	700
South America							
Mine	1,070	1,370	1,590	1,630	1,650	1,650	1,700
Smelter	1,029	1,190	1,200	1,200	1,200	1,400	1,400
Refinery	849	920	920	920	920	950	1,000
Europe							
Mine	1,440	1,550	1,610	1,670	1,770	2,000	2,050
Smelter	1,955	2,010	2,050	2,050	2,050	2,100	2,200
Refinery	2,700	2,710	2,760	2,790	2,840	2,840	2,900
Africa							
Mine	1,520	1,560	1,590	1,650	1,660	1,700	1,750
Smelter	1,555	1,640	1,680	1,680	1,730	1,730	1,750
Refinery	1,134	1,140	1,140	1,140	1,140	1,200	1,200
Asia							
Mine	540	610	700	740	830	870	910
Smelter	880	960	1,020	1,040	1,070	1,070	1,200
Refinery	960	1,000	1,030	1,130	1,130	1,130	1,200
Oceania							
Mine	160	170	180	200	360	400	440
Smelter	135	150	160	160	160	200	200
Refinery	165	170	170	170	170	170	200
World Totals							
Mine	7,180	7,970	8,650	8,970	9,520	9,920	10,250
Smelter	7,979	8,410	8,590	8,620	8,830	9,180	9,520
Refinery	9,098	9,240	9,320	9,650	9,700	9,940	10,300

and refining steps. The projected increase in refinery capacity approximates the increase in mine capacity and should be adequate.

Worldwide, the 43 percent projected increase in mine capacity probably reflects the chronic shortages of copper during most of the 1960-69 decade and the rush by many firms to take advantage of what appeared to be an insatiable demand at very profitable prices. Should the weakness that occurred in the copper market in 1970 persist, some of the announced developments may be delayed. Also some of the expansions assigned to South America are subject to recent political events. Projected smelter capacity is inadequate in comparison to the increased mine capacity after 1970. However, the lead time between announcement and completion of expansions at existing smelters is much shorter than for mine development. Also the use of chemical processing methods bypassing the smelting step may become a significant factor by 1975.

Consumption Pattern

Most copper is consumed as refined metal. The principal user--wire mills--accounted for 61 percent of the total domestic consumption of refined copper in 1969. These mills produce bare wire, insulated wire, and insulated communication wire. Brass mills used 37 percent in the production of sheet, rod, wire, and tubing. Secondary smelter, foundries, chemical plants, and miscellaneous users consumed 2 percent. In addition to refined copper, brass mills used 37 percent of the purchased copper scrap. Primary copper producers and secondary smelters consumed 62 percent of the copper scrap with foundries, chemical plants, and others consuming the remaining 1 percent.

The largest use of copper is in electrical equipment and supplies, which accounted for 50 percent of the 1969 demand. The manufacture of electric motors, power generators, motor-generator sets, dynamotors, fans, blowers, industrial controls, and related apparatus requires the use of copper for the best electrical performance.

Electrical instruments and test equipment, power distribution systems including transformers, bus bars, and switchgear, and electric lighting and wiring equipment require large quantities of copper. Dependable all-weather service on crowded airways requires sophisticated electronic navigation and communication systems that rely on copper in the form of cable and related electric parts. Although aluminum is used for virtually all high-voltage, overhead, power transmission lines, copper still dominates in underground lines and smaller wire markets.

The noncorrosive properties of copper and its alloys result in many uses in the construction industries. Building construction, roofing, plumbing, and brass and bronze for decorative and utilitarian items for public buildings and private homes required 15 percent of the total copper consumed in the U.S. in 1969.

Copper finds widespread usage in the production of nonelectrical industrial machinery, household and commercial air conditioning, farm machinery, and as components in sea water desalination distillation plants, and in pollution control equipment. Copper tubing that can resist the corrosive effects of sea water at temperatures up to 250° F and which also has high heat-transfer capability is used in distillation-type plants for sea water desalination. The demand for copper for use as alloys in heat exchangers, turbines, oil baffles, check values, plates, sheets, bars, etc. took 10 percent of the total U.S. copper demand in 1969.

Almost 12 percent of the copper consumed in the United States is in the transportation industry where it is used in numerous applications by the automobile industry, in railroad transportation, airplane manufacture, and in marine applications. This results both from the trend toward greater convenience and comfort such as power windows, seats, brakes, steering, and air conditioning but also from the more utilitarian uses in radiators, heaters and defrosters, bearings, bushings, carburetors, oil lines, and wiring. Large quantities of copper are used in diesel locomotives, passenger cars, and switching and signal devices.

Copper used for ordnance requirements is related to defense purposes. Of the total copper consumed in 1969, 5 percent went into manitions manufacture.

Miscellaneous uses (chemical, inorganic pigments, jewelry, coinage) of copper approximated 8 percent of the total demand in 1969. Copper is used extensively in watches, clocks, microscopes, projectors and many types of gages. Solid copper, brass and bronze are popular materials in utensils, jewelry, furnishings, and decorative items. Coinage changeover has increased copper consumption.

Copper and copper-alloy scrap was processed at several primary smelters, secondary smelters, refineries, brass mills, and chemical plants to reclaim the copper in various forms for return to supply for consumptive uses. Figure 2 portrays the complexities of the scrap recycling process.

Byproducts and Coproducts

About 98 percent of the domestic mine production of copper continued to come from ores mined primarily for their copper content, with the remainder being recovered from complex or mixed base metal

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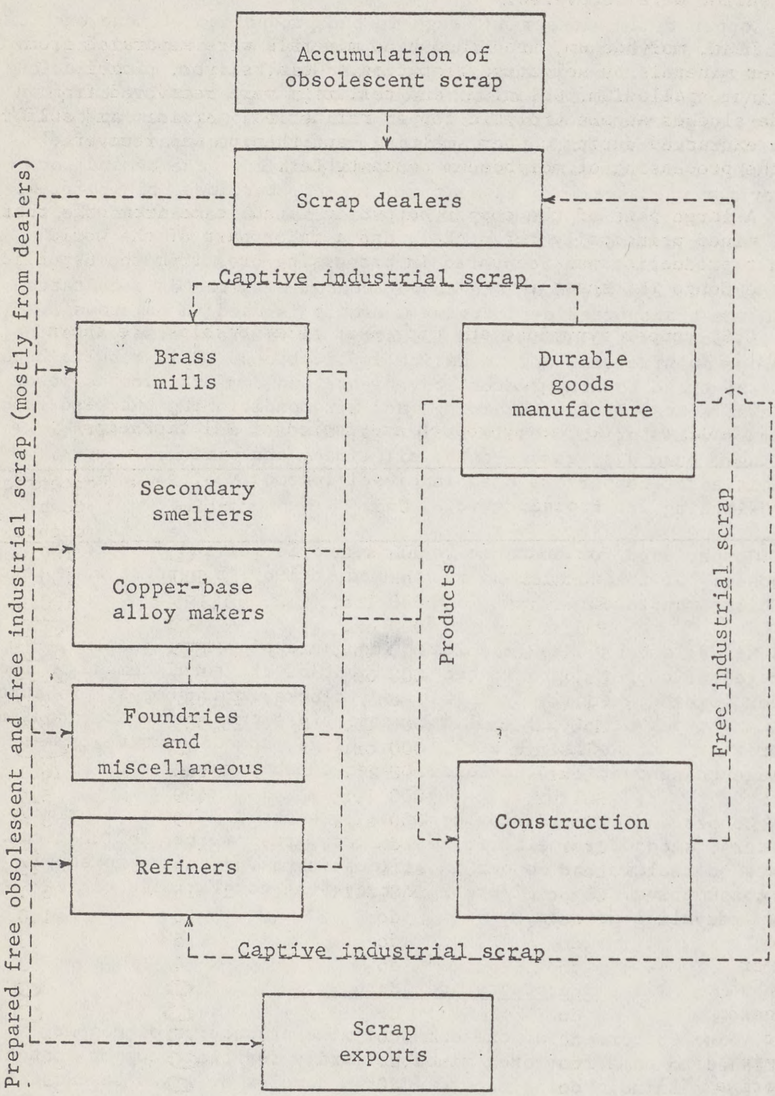
FIGURE 2. Copper Scrap Flow
(Excluding industrial home scrap)



ores. In addition to copper, significant quantities of byproducts and coproducts such as gold, silver, molybdenum, nickel, platinum, selenium, tellurium, palladium, arsenic, rhenium, iron, lead, zinc, and sulfur were recovered.

Lead, molybdenum, iron, and zinc minerals were separated from copper minerals by selective flotation. Gold, silver, nickel, platinum, palladium, selenium, and tellurium were recovered from anode sludges at electrolytic copper refineries. Arsenic and sulfur were extracted during copper smelting, and rhenium was recovered in the processing of molybdenum concentrates.

A large part of the copper output in Canada came from ores that were mined principally for nickel, and a major part of the world cobalt production was recovered in processing ores from the Republic of the Congo (Kinshasa).

U.S. copper byproduct and coproduct relationships are shown in Table 5.

TABLE 5. - Copper Byproduct and Coproduct Relationships

Source	Product	Unit	Quantity	Percent of total output
Copper	Arsenic	000 s.t.	O	100.0
do	Rhenium	lbs.	2,500	100.0
do	Selenium	000 lbs.	1,199	100.0
do	Palladium	000 oz.	O	O
do	Tellurium	000 lbs.	O	O
do	Gold	000 oz.	579	33.4
do	Silver	do	13,627	32.5
do	Molybdenum	000 lb.	28,389	28.4
do	Platinum	000 oz.	O	O
do	Nickel	000 lb.	5,040	16.1
do	Sulfur	000 l.t.	499	5.2
do	Zinc	000 s.t.	19	3.4
do	Iron	do	279	.5
do	Lead	s.t.	89	.1
do	Copper	000 s.t.	1,515	98.1
Lead	do	do	16	1.0
Zinc	do	do	5	.3
Silver	do	do	4	.3
Iron	do	do	O	O
Tungsten	do	do	O	O
Gold	do	do	O	-
Uranium	do	s.t.	O	-
Fluorine	do	d0	O	-

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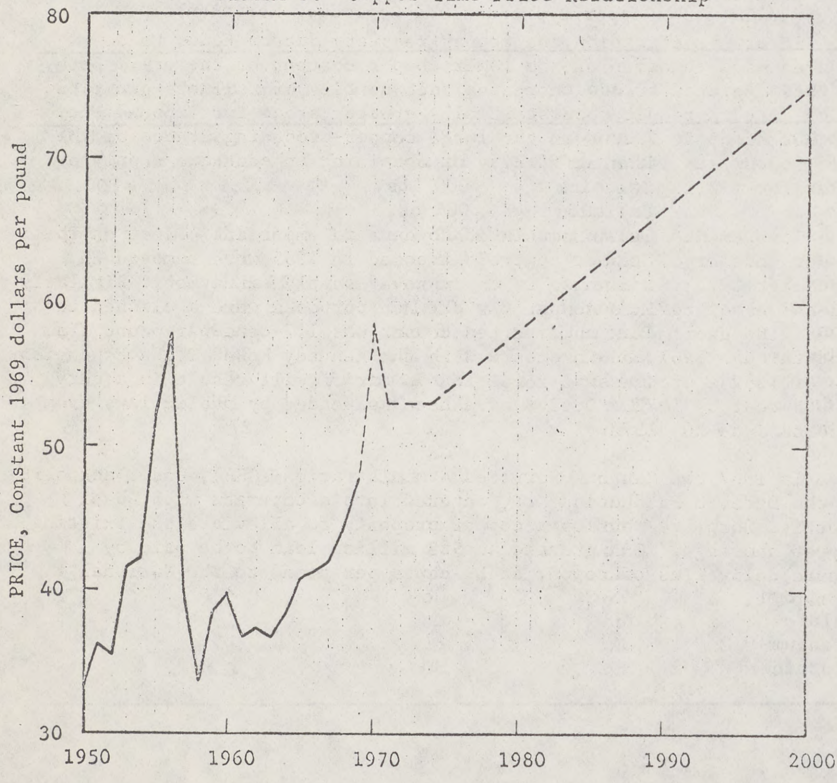
Economic Factors

Prices of copper, in terms of constant 1969 dollars, increased from 33.2 cents per pound in 1950 to 47.9 cents in 1969 and are forecast to reach 75 cents by 2000 as shown in Figure 3. Illustrative of the occasional severe fluctuation of price in response to changes in market conditions was the increase in the price of refined copper from 42 cents to 52 cents per pound during 1969 and to 60 cents by April 1970. Prices on the London Metal Exchange (LME) continued to be substantially above the domestic price, a situation that has persisted since 1964, and near the end of 1969 a 27-cent disparity existed. The considerable expansion in copper productive capacity throughout the world, coupled with reduced demand in the U.S. and elsewhere during 1970, led to a rapid decline of LME copper prices to below the U.S. price by early August. In late October when the LME price was approximately 51 cents, the U.S. producer quotation was reduced by 4 cents to 56 cents. The U.S. producer quotation was reduced to 53 cents in December and to 50 cents in January 1971 in adjustment to the falling LME market which was the equivalent of 46 cents at the time of the last U.S. price change.

FIGURE 3. Copper Time-Price Relationship



Approximately half the cost of producing copper is attributed to the initial mining component of the total production system. The remaining cost components are estimated to be 10 percent for ore beneficiation, 10 percent for smelting, 5 percent for refining, and 25 percent for marketing and overhead including profit. Copper production is considered to be a capital-cost-intensive industry requiring at least $3,000 per ton of new capacity for facilities from mining through refining.

A major factor in the increase of production costs is the long term declining yield of copper from ores which in the U.S. has dropped from an average of 18 pounds of copper per ton of ore in 1950 to 12 pounds in 1969. Some copper deposits currently under development contain only an average of 8 pounds of copper with a cutoff grade of 4 pounds.

The low tenor of copper ore is reflected in the large quantities of material mined and processed per unit of metal produced. Additionally, surface mines, which now account for nearly 90 percent of domestic output, have increased ratios of overburden waste to ore with attendant increased costs.

In ore benefication the copper recovery factor tends to be reduced as a function of the lower copper content of the ore. Both of these related trends increases the quantity of tailings generated which in turn requires substantially greater areas for impoundment. Another economic factor in the large copper-producing States of the arid southwest is the difficulty of obtaining an adequate supply of water for milling.

Government actions continued to have an important effect on the copper industry. Export controls imposed in 1965 were removed in September 1970 in response to an improved supply situation. Similarly set-asides of refined copper for defense purposes were abolished in 1970. The excise tax on imported copper was 1.7-cent-per-pound from 1958 through 1967 and in accord with the Kennedy Round Trade Expansion Act of 1962 a progressive reduction in tariff will result in a duty of 0.8 cent by 1972. Duties have been suspended by public laws from 1966 to June 30, 1972.

In 1967 the General Services Administration (GSA), under authority of the Defense Production Act, entered into a contract with Duval Sierrita Corp. to develop a copper property to alleviate the existing copper shortage. GSA granted an $83 million loan to be paid by future deliveries of copper at 38 cents per pound to the National stockpile.

A national stockpile was established for copper in 1946 and at the end of 1969 contained 260,000 tons, 33 percent of the 775,000-ton objective.

The Office of Minerals Exploration (OME) continued to offer up to 75-percent Government participation in the cost of copper exploration for approved projects that qualify under the terms of the amended program. Three participating contracts involving copper were executed in 1969.

Copper is vulnerable to substitution for many uses such as aluminum for electrical transmission, steel for brass shell casings, and plastics for plumbing pipes. Copper remains the preferred material for electric motors, generators, industrial controls, and automobile radiators although its use in the latter is threatened by aluminum. One offsetting new development is the large quantities of tubing required in desalination plants where copper alloy tubes are a leading contender.

Technology

The transition from mining relatively high-grade veins of copper by underground methods to surface mining of low-grade disseminated type deposits began about 1905. In 1969 open pit mining accounted for 88 percent of the ore and 84 percent of the recoverable domestic mine production of copper. Mine production includes copper recovered as precipitates from waste dump and in-place leaching, amounting to 11 percent of the total.

Most of the ores currently processed are sulfides. During milling they are subjected to crushing, fine grinding, and concentration by flotation. Oxide ores not amenable to flotation are leached with dilute sulfuric acid to take the copper into solution. The copper is then recovered by chemical precipitation on scrap iron (cementation) or by a direct electrowinning process.

Smelting copper concentrates and precipitates is accomplished by roasting to eliminate part of the sulfur and impurities such as arsenic, and melting the charge in a reverberatory furnace with suitable fluxes. In the furnace the lighter impurities combine and float to the top as a slag to be skimmed off and discarded, while the copper, iron, sulfur, and any contained precious metals form a product known as matte which collects and is drawn off the lower part of the furnace. The molten matte is transferred to a converter where blowing air through the matte burns off the sulfur, oxidizes the iron for removal in a slag, and yields a 98 to 99 percent "blister" copper product.

The blister copper may be upgraded to fire refined copper by melting in an anode furnace and removing the principal impurity, oxygen, in a reducing atmosphere provided by use of green logs thrust into the melt. However, most of the blister copper is cast into copper anodes for electrolytic refining. These anodes and thin copper starting sheets, or cathodes, are suspended in tanks containing a solution of copper sulfate and sulfuric acid. An electric current passed through the solution dissolves copper from the anodes and deposits it in refined form on the cathodes. The sludge that collects on the bottom of the tank contains the gold, silver, and other valuable constituents for a separate recovery system. Refined copper is cast into wire bars, ingots, or other shapes and sent to fabricating mills for conversion to sheet, strip, tube, rod, wire, or other semimanufactured products.

In the process of copper production substantial quantities of solid wastes are generated in the form of waste stripping at the mine, tailings at the concentrator, and slag at the smelter. Lesser but more obnoxious quantities of sulfur compounds and particulate matter escape to the atmosphere in the smelting process.

Operating Factors

Productivity in the copper industry in terms of output per man-hour for mining, milling, and smelting-refining compared with grade of ore and production for selected years are shown in Table 6.

TABLE 6. - Productivity in the Copper Industry

Year	Recoverable copper in ore (percent)	Production Thousand tons			Output per man-hour pounds of copper			
		Mine	Mill	Smelter	Mine	Mill	Smelter 1/	Total
1950	0.89	909	797	911	48.7	100.7	60.0	21.2
1960	0.73	1,080	963	1,143	62.0	146.7	77.6	28.0
1969	0.60	1,545	1,264	1,663	74.7	155.0	106.8	34.3

1/ Includes refinery employment and some refinery man-hours chargeable to refined production derived from foreign ores.

The gain in labor productivity from 1950 to 1969 has been impressive, especially in mining and milling where the grade of ore has simultaneously declined by 33 percent. Large capital investments for greater mechanization, adoption of new technologies, use of automation, and economics of large-scale operations were important factors in achieving the production efficiencies.

Operating supplies consumed in mining are principally explosives, fuel or energy for operating equipment, and spare parts for maintenance of equipment. In milling, steel consumed for grinding the ore approximates 1-½ pounds per ton of ore processed and is probably the largest supply item. The cost of flotation reagents is about 1-cent-per-pound of copper produced. In smelting-refining the principal supply items are fluxes for the smelting charge and energy for electrolytic refining.

Ecological concern over emission of sulfur compounds to the atmosphere during smelting is probably the most pressing immediate problem facing the copper industry. It has already resulted in curtailment of production at some smelters owing to enforcement of new air pollution regulations, and delay in construction of new smelter facilities pending a resolution of uncertainties surrounding new pollution standards and the proper technology to meet the anticipated requirements.

The number of employees in the copper industry in 1969 - exclusive of office workers - totaled 22,300 at mines and mills and 11,700 at smelters and refineries. Widespread mechanization and large-scale operations have increased the need for mechanics, technicians, and operators of many kinds of machines, while eliminating the need for a large number of unskilled laborers.

Transportation occupies an important role in the copper industry. Owing to the low copper content, production economics dictate that the ore concentrating plant be located relatively near the mine with transport by truck, rail, or conveyor. Since the concentrates only average 25 percent copper most smelters are located to minimize transportation of concentrates. Location of refineries is determined largely by evaluating transportation facilities, availability of labor, and nearness to copper markets.

Flotation is the most efficient concentrating process available and copper recovery averages about 84 percent. Smelter recoveries average about 98 percent and losses in refining are negligible.

In mining 226 million tons of copper ore in 1969, about 622 million tons of "waste" material was discarded. Copper content of the waste varied from the cutoff grade at any particular mine to zero. Waste dumps with significant copper content are subjected to acid leach solutions which percolate through the dump and recover an estimated 15 percent of the contained copper.

The 223 million tons of copper ore milled in 1969 produced approximately 5 million tons of concentrates leaving 218 million tons of tailings representing a waste disposal problem.

Production of 1.7 million tons of blister copper at smelters was accompanied by an estimated 4.7 million tons of solid waste in the form of slag. As chalcopyrite, the principal copper mineral, contains about equal parts of copper and sulfur, it is assumed that approximately 1.2 million tons of sulfur contained in concentrates were generated in gases. Production of sulfuric acid is reported to have consumed 0.2 million tons of the sulfur leaving 1.0 million tons presumably discharged into the atmosphere. Reduction of this discharge to meet new air pollution standards poses a serious operating problem.

OUTLOOK

Demand

Total U.S. demand for copper in 2000 is forecast to range between 7.6 and 15.7 million short tons as summarized in Table 7 and detailed in Table 8. The most probable demand within the range is estimated at 11.2 million tons representing a growth rate of 4.2 percent during 1969 to 2000. Demand for each of the major end uses was projected to 2000 by means of a forecast base obtained by relating 1969 demand to the most appropriate economic indicator selected from electrical energy, gross national product (GNP), new construction, or total population. The validity of each forecast base quantity was tested by contingency assumptions for technology and other influential factors resulting in the creation of a forecast demand range for each end-use in 2000. Analysis, based largely on knowledge and judgment of emerging trends of utilization, was applied to each end use to determine the most probable point within the range. The sum of the most probable demand for each use established the total probable demand of copper in 2000.

Total demand for copper in the rest of the world is forecast to range from a low of 16.8 million tons to a high of 34.9 million tons in 2000, corresponding to annual growth rates of 3.2 and 5.6 percent, respectively, during the forecast period. These rates of growth are a composite based on the assumption that demand in industrialized, developed countries will increase at rates similar to the U.S. demand while in developing nations the rates of growth will be considerably higher. Based on similar assumptions, the probable copper demand for 2000 in the rest of the world is 25.0 million tons.

Assignment of 55 percent of U.S. forecast demand as primary material was based upon approximate continuation of the 1969 data. For the rest of the world the assigned distribution was approximately 68 percent primary material.

The forecast range and probable demand for the United States was derived in accordance with the following analysis for each major end use, considering the possible effects of, technical, economic, social, and other contingencies.

Electrical Equipment and Supplies.--The forecast base of 8.75 million tons for demand in 2000 was obtained by relating electrical apparatus and electrical transmission sectors to the economic indicator for electrical energy, and the communications and household appliance sectors to GNP. Increased emphasis on safety, comfort, recreation, and a pollution-free environment by an affluent society will probably be reflected in great demand for electrical applications. Automation, including use of computers, should spur

Revised May 7, 1971

TABLE 7. - Summary of Forecasts of U.S. and Rest of World Copper Demand, 1969-2000
(Million short tons)

	1969	2000 Forecast Range			Probable Average growth rate 1969-2000 (percent)
		Low	High	Probable	
United States					
Primary	1.696	4.2	8.6	6.1	4.2
Secondary	1.401	3.4	7.1	5.1	4.2
Total	3.097	7.6	15.7	11.2	4.2
Cumulative (primary)	-----	91.5	159.7	120.9	---
Rest of World					
Primary	4.80	12.6	26.2	18.8	4.5
Secondary	1.60	4.2	8.7	6.2	4.5
Total	6.40	16.8	34.9	25.0	4.5
Cumulative (primary)	----	269.7	480.5	365.8	---
World					
Primary	6.496	16.8	34.8	24.9	4.4
Secondary	3.001	7.6	15.8	11.3	4.4
Total	9.497	24.4	50.6	36.2	4.4
Cumulative (primary)	-----	361.2	640.2	486.7	---

TABLE 8. - United States Projections and Forecasts for Copper Demand by End-use, 1969 to 2000
(Million short tons)

	1969	Year 2000			
		Forecast base	United States Contingency Forecasts		
			Forecast range		
			Low	High	Probable
Electrical equipment and supplies	1.54	8.75	4.6	9.9	7.0
Construction	.48	1.80	1.0	2.0	1.0
Industrial machinery, except electrical	.32	1.00	.8	1.2	1.0
Transportation	.36	1.15	.6	1.4	1.2
Ordnance	.16	.28	.1	.4	.3
Other uses	.237	.70	.5	.8	.7
Total	3.097	----	7.6	15.7	11.2

use of electrical equipment. The trend to underground power distribution systems is likely to boost the use of copper over competitive materials for technological reasons. Because of these strong growth factors the high of the forecast range was set at 9.9 million tons.

A number of contingencies inhibiting the use of copper was considered to derive the low of 4.6 million tons. These include substitution of aluminum for copper, copper clad aluminum, advanced power generation systems not requiring generators, cryogenic techniques in power transmission, microminiaturization of communication circuitry, and use of satellites for communications.

The factors of relative price advantages of substitute materials and technological developments reducing unit material requirements is expected to partly offset the large increase in the demand of copper for electrical purposes and, on balance, the probable use is placed at 7.0 million tons.

<u>Construction</u>.--A forecast base of 1.80 million tons for 2000 was obtained by relating the demand for this category to the new construction economic indicator. A plus factor in use of copper for construction is the prestige image desired by an affluent society in their housing. The technological developments of copper cladding many building materials should promote this decorative use. Another factor may be the insistence for superior performance in materials to combat future high maintenance costs.

Factors curtailing the use of copper in construction include the trend to multiple housing units which reduces material needs per unit and the use of substitute material to replace the relatively high priced copper.

In consideration of the preceding contingencies the demand range was forecast to be from 1.0 to 2.0 million tons. The probable demand was placed at 1.0 million tons owing to the strong substitutability incentive.

<u>Industrial Machinery, Except Electrical</u>.--Projection of this end use category at the anticipated GNP growth rate yields a forecast base of 1.0 million tons for 2000. Anticipated strong growth in the areas of air conditioning and desalination where copper alloys are a preferred material should enhance copper demand. A supplementary consideration is the relative ease of copper fabrication which will become more important as labor cost rise faster than raw material costs. The principal deterrent to use of copper for industrial machinery is the high cost relative to alternate choice materials.

Owing to the cited strong growth factors the high of the forecast range was established at 1.2 million tons and because of the substitutability pressure the low was set at 0.8 million tons. The plus and minus factors appear equally likely, therefore, the probable demand was set at 1.0 million tons.

Transportation.--The forecast base of 1.15 million tons for this use was related to the GNP growth rate. Growth of demand for copper in the transportation industries could reach a forecast high of 1.4 million tons through increased number of cars per family, continued popularity of house trailers for recreation, greater leisure time, installation of rapid transit systems for major cities, and expected growth in aircraft passenger miles traveled. On the other hand, environmental restrictions excluding automobiles for metropolitan commuting as an anti-pollution measure, and loss of copper markets to aluminum and plastics could reduce demand to a forecast low of 0.6 million tons. Trends toward improved mass transportation systems particularly for short distance traveling and expansion in railroad transportation indicate a probable demand of 1.2 million tons of copper in 2000.

Ordnance.--Demand growth for ordnance applications was projected at the growth rate for total population and resulted in a forecast base of 0.28 million tons in 2000. World political instability requiring military expenditures for arms exports to allied countries could create a demand for copper of 0.4 million tons. Universal disarmament, however, could limit the use of copper to a low of 0.1 million tons. Expectation of a peacetime military strength indicates a probable demand of 0.3 million tons of copper in 2000.

Other uses, Including Jewelry, Chemical, Pigments, and Coinage.--Demand for the many miscellaneous uses for copper was forecast to grow at the same rate as population to a forecast base of 0.7 million tons of copper. The popularity of copper jewelry for esthetic purposes together with continued research in other areas may result in increased requirements for copper chemicals and inorganic pigments. Copper as a trace element is needed to sustain the life of plants, animals, and humans. Copper in coinage has extended copper's usefulness and the technique of laminating or cladding copper with other materials may result in its use in diverse applications. These contingencies could result in a copper demand as high as 0.8 million tons in 2000. On the other hand, the use of alternate materials and the use of credit cards in place of coinage could lessen the demand for copper to 0.5 million tons. However, it is improbable that the copper demand for the many miscellaneous items in which it is used would be substantially below the high demand. Thus, the probable demand is set at 0.7 million tons.

Supply

Assigned available domestic reserves of copper at the average 1969 price ($0.479 per pound) were 81 million tons of recoverable copper. An advance in price to $0.80 increases the catalogued resources to 99 million tons (see Table 2). Paradoxically, much of the lower production cost reserves are also the lower tenor deposits occurring near the surface and amenable to surface mining. Deposits with higher waste to ore ratios or accessible only by underground mining methods must contain a larger percentage of copper to be equally economic. Obviously considerations of total demand and results of future exploration will determine the order of exploitation and any changes in the distribution between surface and underground methods.

Some reserves may not be producible for unforeseen social constraints, management decisions, or other reasons. However, it is anticipated that new reserves discovered in the interim and new technology will approximately offset ecological or other obstacles inhibiting production. Accordingly it is estimated that probable supply from domestic mines for 1969 to 2000 will equal the 99 million tons of assigned resources. This probable supply would permit production to increase at an average annual compound growth rate of 3.8 percent.

World reserves of copper are estimated to be 296 million tons at the equivalent domestic 1969 price and 402 million tons at a price of $0.80. Tenor of ore deposits in the important copper producing countries of Chile, Peru, the Congo, and Zambia are much higher than most U.S. deposits. However, the relatively large revenues derived through taxes, royalties, or ownership of copper mines are vital to continuance of the economy of these countries and can be considered an added production cost which must be taken into account in assigning reserves.

The 1969 to 2000 world supply from mines is estimated to be 402 million tons using a rationale similar to that described for United States estimated supply. This probable supply would permit production to increase at an average annual growth rate of 3.6 percent.

Possible Advances in Technology

Advances in technology over the next 30 years are likely to exert a tremendous effect on all phases of the copper industry from exploration through utilization. Some of these changes appear inevitable from present trends while others are only dimly perceived from suggestive research.

In mineral discovery new techniques in geochemical exploration, detections of emissions of heat and trace elements by airborne recording instruments, and an improved understanding of ore forming processes will assist in directing exploration to areas of greatest potential. Greater application of geophysical instrumentation on surface and in bore holes should improve exploration techniques.

Open pit mining systems will undoubtedly continue the trend towards use of larger equipment and more extensive use of conveyor belts and draglines where feasible to reduce materials handling costs. Underground mining could be revitalized by more efficient, system-integrated equipment for advancing the mine openings, breaking ore, and haulage of material.

The problem of SO_2 emissions from the smelter is accelerating research to seek solutions that could have a tremendous effect on many aspects of copper production technology. Continuation of present pyrometallurgical methods with improved gas collection systems, including reduction of gas volume by oxygen injection in the converters will permit more efficient removal of the SO_2 as sulfuric acid or as a precipitate caused by reaction with some selected reagent. As an alternative to pyrometallurgy, chemical-processing systems recovering copper by precipitation or electro-deposition from leach solutions might be developed. These systems generally recover elemental sulfur and would eliminate the conventional smelting-refining practices of producing copper.

Use of ion exchange electrowinning technology will probably replace precipitation-smelting-refining practices in recovery of copper from waste dump leach solutions. This practice could reduce production costs and permit higher total yield of copper from the dump since loss of percolation by deposition of iron salts would be prevented. Availability of large quantities of low cost sulfuric acid as a consequence of smelter pollution controls along with possible development of new leaching agents may contribute to increased waste dump copper recovery. It will also be a factor for proposed in-situ leach recovery systems of large, low grade copper deposits that could be fractured by use of an underground nuclear detonation.

Results of basic research on the properties of materials could have profound effects on the utilization of copper. Use of super pure elements and alloying under different environments such as in a vacuum, a magnetic field, or an inert atmosphere yields materials having new characteristics with obvious implications to changes in future copper use patterns.

Possible Changes in Supply-Demand Relationships

Domestic primary production of copper in 1969 was 1,545,000 tons and the U.S. demand for primary copper was 1,696,000 tons. Therefore domestic production supplied 91 percent of the total U.S. demand for primary copper.

The total U.S. demand for primary copper in 2000 is projected at 6,100,000 tons. If the present percentage met from domestic sources prevails at that time, U.S. primary copper production in 2000 would be 5,551,000 tons.

For speculative purposes Figure 4 compares this sum to the amount of domestic primary production in 2000, as derived from a projection of historical production records. A straight line projection of domestic production during the past 20 years suggests that primary copper production in 2000 might be 2,132,000 tons if this historical trend persists.

Cumulative domestic requirements for primary copper, using the probable demand will be 121 million tons. Maintenance of the constant ratio rate of domestic production to domestic primary requirements would require a total cumulative output between 1969 and 2000 of 103 million tons. The probable copper supply from domestic ores during the forecast period is estimated to be 99 million tons.

Comparing the cumulative domestic primary copper forecast requirement of 92 to 160 million tons with domestic availability of 81 million tons at 1969 prices indicates a substantial shortfall within the entire range of forecast demand if supply should have to be met only from domestic reserves. The 99 million tons of supply considered available at an increased price would be adequate for the low of the forecast range but would be 22 million tons short for the cumulative probable demand requirements and 61 million tons short if the high of the range were realized.

A supply-demand analysis for the rest of the world shows cumulative primary requirements of 270 to 481 million tons compared with 215 million tons of reserves. The supply of 303 million tons considered available from known resources at an increased price would be sufficient for the low of the forecast demand range but would be 63 and 178 million tons short for the forecast probable and high demand, respectively.

Under the limiting assumptions made in the preceding analysis, the United States faces the threat of a long term shortage of copper owing to inadequate domestic supply for probable demand from 1969 to 2000 and the doubtful reliance on imports for the balance.

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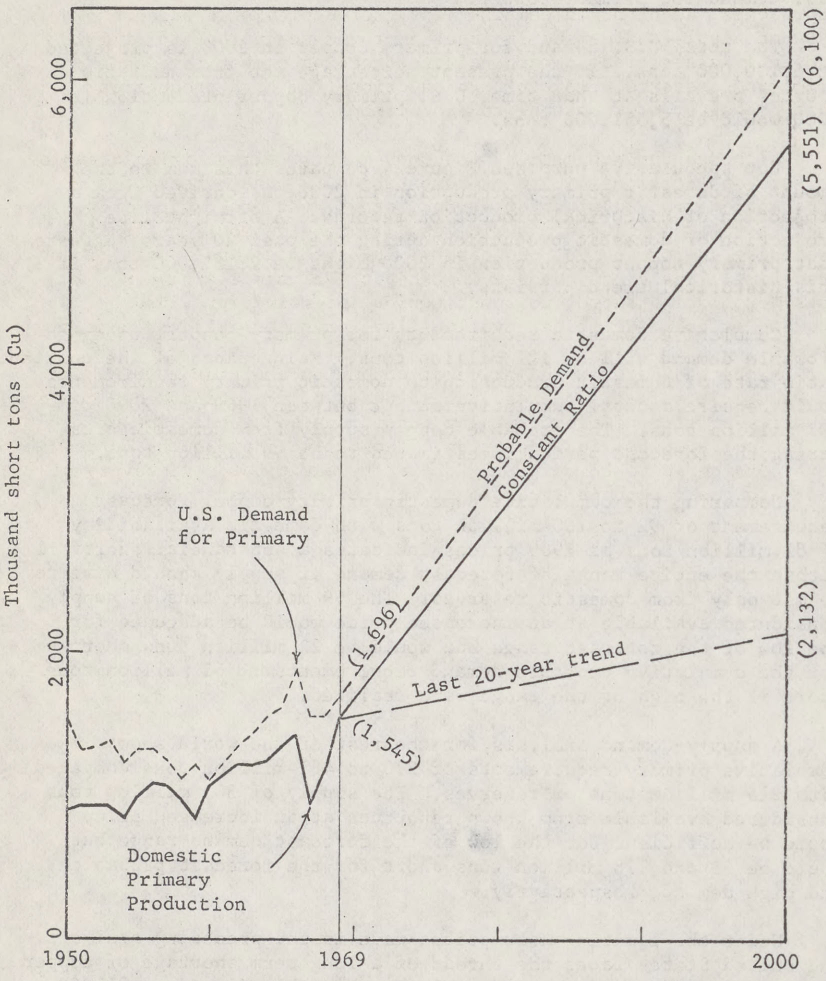
FIGURE 4. Comparison of Domestic Primary Production and Demand Projections



A solution to the potential copper deficit could result from discovery of new reserves. Extensive exploration in recent years, promoted by continuing supply shortages and concern over nationalization of copper investments, may significantly add to assigned reserves when announcements of the success of the various projects are eventually made by the respective companies. Other alternative approaches, alone or in combinations, for achieving a balance between supply and demand include: improved technology to utilize presently classified submarginal resources at competitive costs; price increases to bring forth production from high production cost deposits; or resorting to substitutes.

Although the properties of copper make it almost irreplaceable in some applications, it faces competition in other areas of consumption from aluminum, plastics, steel, and other materials. Changes to a substitute material usually require modifications of processes and/or design, new capital investments, and a significant lead time. Therefore changes in use pattern normally have a considerable lag factor to substitution incentives provided by changes in relative price, availability, or technical developments.

Projected data on the price of copper to the year 2000, shown in Figure 3, reflects the decline in tenor of remaining known copper deposits or more difficult mining conditions and resolution of ecological problems in production. Those upward pressures on costs were considered to be partially offset by anticipated discovery of new reserves, improved technology, and scale of operations.

Optional Trend Analysis System

The Bureau of Mines has found that a comparison of apparent per capita consumption of mineral commodities to per capita GNP is a useful means of detecting changes in global demand patterns.

To avoid bogging down in a mass of statistical data, and to avoid distortions where the validity of reported information seems questionable, we have limited these comparisons to the major free world consuming sectors and to a selected number of key commodities.

It is immediately obvious that, geographically, the action deserving particular attention is taking place in three sectors.

North America (Canada and U.S.)

Europe (particularly the Common Market)

Japan

Accordingly, a fair appreciation of global demand trends may be gained by examining six commodities in seven countries. (The available chart does this at five year intervals from 1950 through 1969).

To further simplify the comparison a graphic presentation of each commodity, comparing country positions in 1950 directly with 1969, provides a fairly accurate picture of trends during this period.

In this kind of comparison it must be clearly understood that the phrase "per capita demand" represents the result of dividing national apparent consumption by population. Thus, per capita demand includes the materials entering end products for domestic consumption as well as those materials used in items for export.

Per Capita Gross National Product compared with Per Capita Mineral Demand for Selected Countries, 1950-1969

Year and Country	Population Millions	Gross National Product		Aluminum Demand		Copper Demand		Lead Demand		Steel Demand		Zinc Demand		Petroleum Demand	
		Total Billion $1969	Per Capita $1969	Total Thousand S.T.	Per Capita lbs.	Total Thousand S.T.	Per Capita lbs.	Total Thousand S.T.	Per Capita lbs.	Total Thousand S.T.	Per Capita lbs.	Total Thousand S.T.	Per Capita lbs.	Total Million bbl.	Per Capita bbl.
1950															
United States	152.3	455.1	2,988	896.4	11.8	1,424.4	18.7	885.2	11.6	94,744	1,244	967.1	12.7	2,333.5	15.3
Canada	13.7	28.3	2,057	65.2	9.5	106.9	15.6	54.7	8.0	4,616	674	54.4	7.9	118.3	8.6
France	41.7	50.6	1,211	49.3	2.4	127.0	6.1	65.1	3.1	7,392	355	105.2	5.0	72.7	1.7
Germany, West	50.0	47.4	948	54.9	2.2	200.2	8.0	110.8	4.4	11,185	447	130.1	5.2	24.5	.5
Italy	46.8	28.9	619	52.5	2.2	67.7	2.9	48.1	2.1	3,229	138	36.9	1.6	31.7	.7
United Kingdom	50.6	65.8	1,305	202.6	8.0	375.6	14.9	183.0	7.2	15,482	612	265.3	10.5	124.4	2.5
Japan	82.9			20.9	0.5	70.5	1.7	27.1	0.7	4,582	111	56.8	1.4	15.5	.2
1955															
United States	165.9	561.1	3,382	1,754.9	21.2	1,502.0	18.1	809.9	9.8	107,119	1,291	1,119.8	13.5	3,059.4	18.4
Canada	15.7	36.9	2,344	91.5	11.7	139.3	17.7	69.4	8.8	6,717	856	66.7	8.5	200.1	12.7
France	43.4	62.4	1,436	119.3	5.5	205.0	9.4	141.9	6.5	13,391	617	170.9	7.9	125.6	2.9
Germany, West	52.4	74.1	1,415	239.3	9.1	405.2	15.5	220.5	8.4	20,208	771	241.6	9.2	80.5	1.5
Italy	48.2	38.6	802	68.6	2.8	97.5	4.0	62.0	2.6	5,894	245	62.1	2.6	75.6	1.6
United Kingdom	51.2	75.1	1,473	320.5	12.6	555.7	21.7	237.5	9.3	21,343	834	281.5	11.0	186.1	3.6
Japan	89.0	42.2	474	53.0	1.2	123.1	2.8	48.9	1.1	10,383	233	119.3	2.7	69.3	.8
1960															
United Kingdom	180.7	624.9	3,458	1,686.0	18.7	1,398.0	15.5	581.7	6.4	99,070	1,097	877.9	9.7	3,502.7	19.4
Canada	17.9	45.1	2,518	114.3	12.8	117.8	13.2	44.5	5.0	6,069	678	53.5	6.0	306.6	17.1
France	45.7	78.6	1,721	234.5	10.3	265.4	11.6	178.0	7.8	15,343	671	189.3	8.3	204.1	4.5
Germany, West	55.4	108.6	1,960	335.1	12.1	568.7	20.5	297.6	10.7	32,199	1,162	323.7	11.7	229.1	4.1
Italy	49.6	50.6	1,018	124.0	5.0	203.9	8.2	75.5	3.0	10,170	410	88.6	3.6	164.6	3.3
United Kingdom	52.4	85.8	1,640	396.3	15.1	617.6	23.6	215.2	8.2	24,518	936	304.1	11.6	344.2	6.6
Japan	93.2	64.6	693	163.8	3.5	335.1	7.2	122.7	2.6	21,468	461	208.7	4.5	242.4	2.6
1965															
United Kingdom	194.6	791.4	4,067	3,093.4	31.8	2,058.0	21.2	716.4	7.4	140,746	1,447	1,354.1	13.9	4,148.5	21.3
Canada	19.6	59.5	3,037	186.4	19.0	224.6	22.9	62.8	6.4	11,480	1,171	104.6	10.7	416.9	21.3
France	48.8	104.4	2,142	274.0	11.2	316.4	13.0	159.4	6.5	17,825	731	204.7	8.4	397.3	8.1
Germany, West	59.0	138.8	2,350	427.0	14.5	591.2	20.0	364.6	12.4	35,148	1,191	389.2	13.2	586.5	9.9
Italy	51.6	65.4	1,268	135.0	5.2	211.6	8.2	69.8	2.7	13,339	517	140.0	5.4	357.9	6.9
United Kingdom	54.4	101.1	1,857	400.8	14.7	716.6	26.3	216.4	8.0	25,497	937	310.9	11.4	545.1	10.0
Japan	98.0	104.0	1,062	370.4	7.6	471.2	9.6	162.4	3.3	31,791	649	363.2	7.4	636.2	6.5
1969															
United States	203.2	931.4	4,584	3,809.6	37.5	2,195.0	21.6	942.6	9.3	152,868	1,505	1,368.3	13.5	5,112.4	25.2
Canada	21.1	72.7	3,446	216.5	20.5	258.5	24.5	74.0	7.0	12,897	1,222	127.2	12.1	517.6	24.5
France	50.3	130.7	2,596	404.7	16.1	369.1	14.7	218.8	8.7	24,622	979	263.5	10.5	607.4	12.1
Germany, West	60.8	164.7	2,707	708.0	23.3	722.8	23.8	416.5	13.7	44,213	1,454	474.6	15.6	850.7	14.0
Italy	53.2	82.3	1,548	284.4	10.7	262.3	9.9	133.7	5.0	20,654	776	179.4	6.7	617.9	11.6
United Kingdom	55.5	109.8	1,978	436.6	15.7	602.7	21.7	174.7	6.3	26,810	966	318.4	11.5	724.0	13.0
Japan	102.3	166.4	1,626	899.5	17.6	889.5	17.4	206.8	4.0	67,852	1,327	661.3	12.9	1,186.2	11.6

Similarly, individual country GNP data must be reduced to a common base for comparison purposes -- in this case all have been converted to 1969 U.S. dollars and the results are divided by population to provide the base for each comparison.

Country	Per Capita GNP - 1969 Dollars		
	1950	1969	Increase Percent
United States	2,988	4,584	53
Canada	2,057	3,446	68
France	1,211	2,596	114
Germany, West	948	2,707	186
Italy	619	1,548	150
United Kingdom	1,305	1,978	52
Japan	474 1/	1,626	243

1/ 1955 Data - 1950 Data Not Available.

During the period described the relative increase in population in the seven countries merit attention.

Country	Population		
	1950 - Millions	1969 - Millions	Increase-Percent
United States	152.3	203.2	33
Canada	13.7	21.1	54
France	41.7	50.3	21
Germany, West	50.0	60.8	22
Italy	46.8	53.2	14
United Kingdom	50.6	55.5	10
Japan	82.9	102.3	23

The individual commodity comparisons are obviously subject to a variety of interpretations and the factors entering into the apparent changes in world demand patterns are numerous and complex.

One certainty is suggested by a careful comparison of the slope of the United States trends to those elsewhere. Outside of the United States, a very large share of the apparent per capita demand is attributed to materials in exported goods. Thus, the present U.S. deficit in U.S. balance of trade might be at least partially explained through this type of analysis.

Aluminum

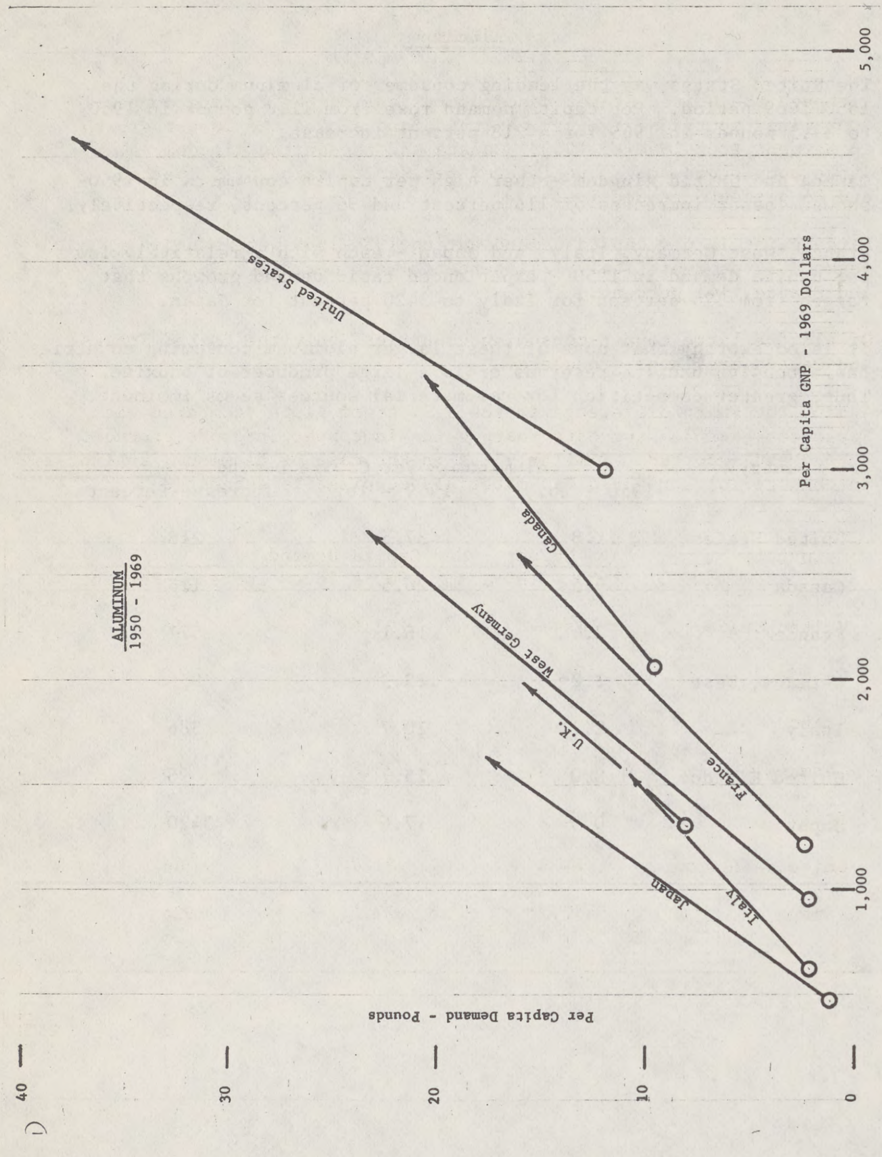
The United States was the leading consumer of aluminum during the 1950-1969 period. Per capita demand rose from 11.8 pounds in 1950 to 37.5 pounds in 1969 for a 218-percent increase.

Canada and United Kingdom--other high per capita consumers in 1950-showed lesser increases of 116 percent and 96 percent, respectively.

France, West Germany, Italy, and Japan - each with a relatively low per capita demand in 1950 - experienced rapid demand growths that ranged from 386 percent for Italy to 3420 percent for Japan.

It is noteworthy that none of these larger aluminum-consuming countries has extensive bauxite reserves or is a large producer of bauxite. Thus, greater competition for raw material sources seems imminent.

Country	Aluminum - Per Capita Demand		
	1950 - lb.	1969 - lb.	Increase-Percent
United States	11.8	37.5	218
Canada	9.5	20.5	116
France	2.4	16.1	571
Germany, West	2.2	23.3	959
Italy	2.2	10.7	386
United Kingdom	8.0	15.7	96
Japan	0.5	17.6	3420


ALUMINUM
1950 - 1969
Per Capita Demand - Pounds
Per Capita GNP - 1969 Dollars
0
10
20
30
40
1,000
2,000
3,000
4,000
5,000
United States
Canada
France
West Germany
U.K.
Italy
Japan

Copper

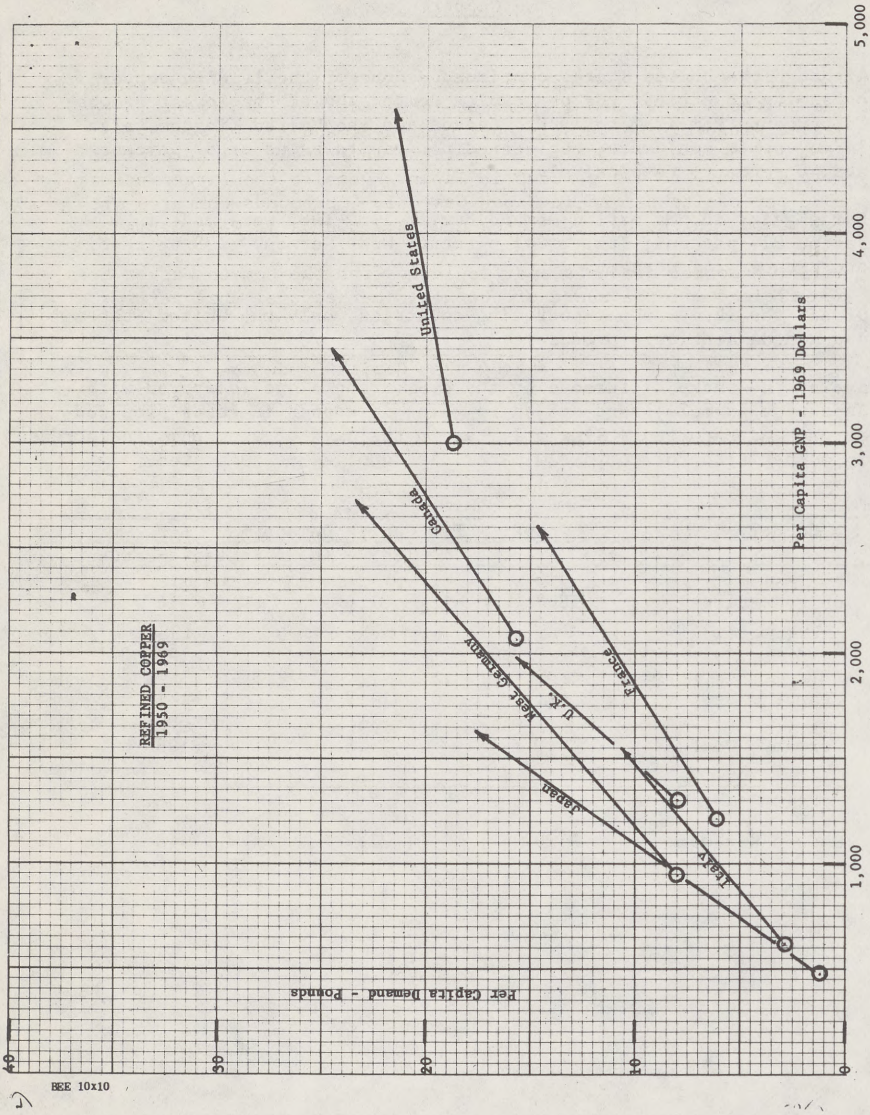
Although the United States continued as one of the leading copper-consuming countries, the per capita demand showed the lowest growth, 16 percent from 1950 to 1969. Canada and the United Kingdom, also large copper consumers, registered per capita gains of 57 percent and 46 percent, respectively.

Large gains in per capita demand during 1950-1969 were made in Japan, 924 percent; Italy, 241 percent; West Germany, 198 percent; and France, 141 percent.

Of all the large copper-consuming countries, only the United States and Canada are large producers.

Again, the sharp difference in the U.S. trend slope (compared with Japan for example) suggests sharp gains in copper in goods produced abroad and exported. Similarly, as in the case of aluminum, an increase in competition for world raw materials supplies is suggested.

Country	Copper - Per Capita Demand		
	1950 - lb.	1969 - lb.	Increase-Percent
United States	18.7	21.6	16
Canada	15.6	24.5	57
France	6.1	14.7	141
Germany, West	8.0	23.8	198
Italy	2.9	9.9	241
United Kingdom	14.9	21.7	46
Japan	1.7	17.4	924


REFINED COPPER
1950 - 1969
Per Capita GNP - 1969 Dollars
Per Capita Demand - Pounds
United States
Canada
West Germany
France
U.K.
Japan
Italy
1,000
2,000
3,000
4,000
5,000
0
10
20
30
40
BEE 10x10

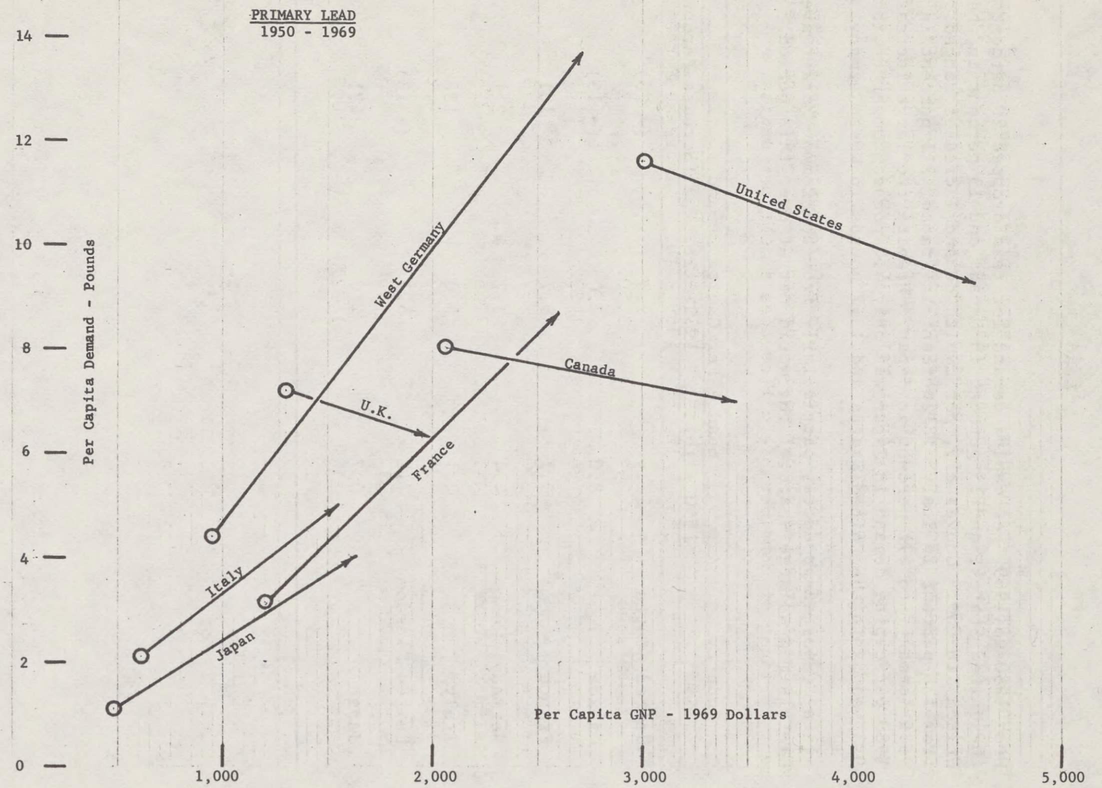
Lead

From 1950 to 1969, per capita demand for lead dropped 20 percent in the United States, and 13 percent in Canada and 13 percent in the United Kingdom. Conversely, per capita demand increases ranged from 138 percent in Italy, 181 percent in France, 211 percent in West Germany, to 471 percent in Japan. Despite the large increase, 1960 per capita demand in Japan was only 4.0 pounds compared with 9.3 pounds in the United States and 13.7 pounds in West Germany.

Again, exported products, particularly from the Common Market area, have claimed a large share of the world market over this period.

Country	Lead - Per Capita Demand		
	1950 - lb.	1969 - lb.	Increase-Percent
United States	11.6	9.3	(- 20)
Canada	8.0	7.0	(- 13)
France	3.1	8.7	181
Germany, West	4.4	13.7	211
Italy	2.1	5.0	138
United Kingdom	7.2	6.3	(- 13)
Japan	0.7	4.0	471

PRIMARY LEAD
1950 - 1969

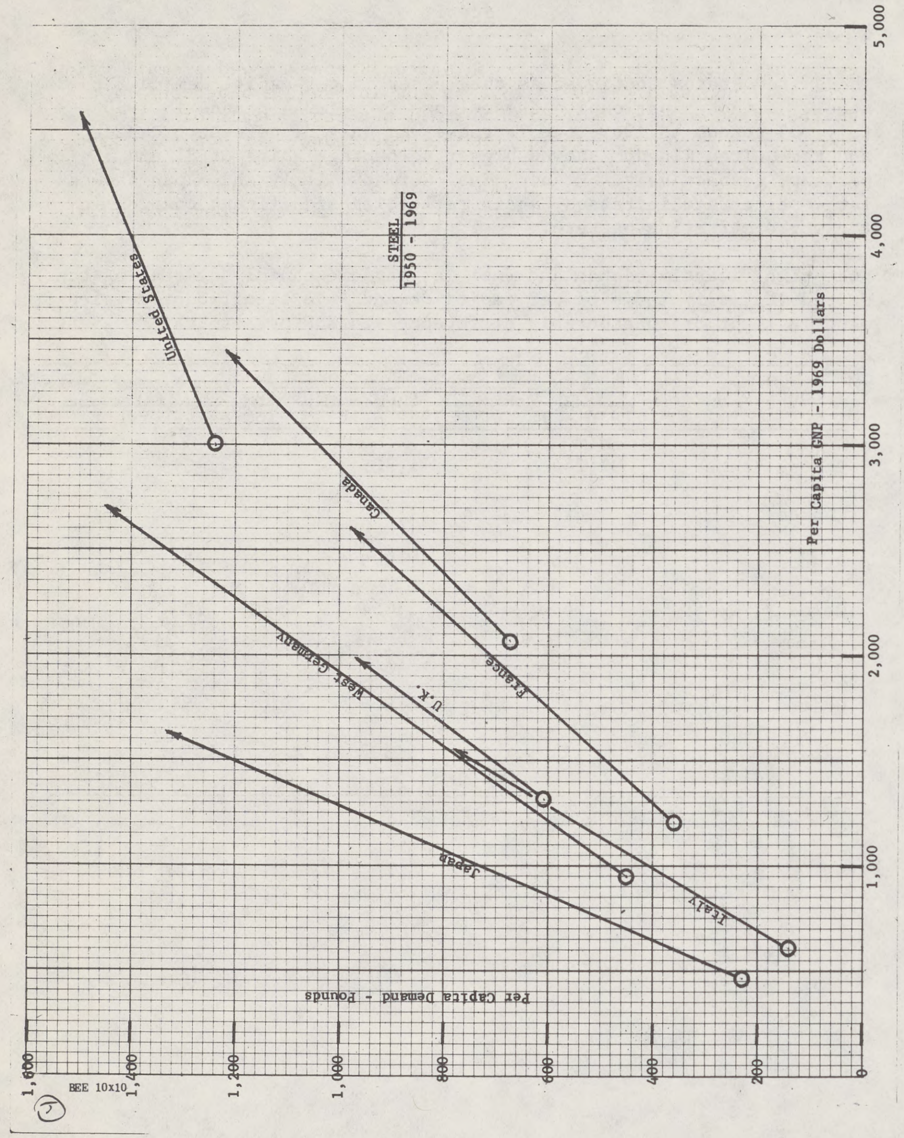


Steel

The United States continued as the leader in per capita demand for steel. Although per capita demand rose from 1,244 pounds in 1950 to 1,505 pounds in 1969, the increase was only 21 percent. Canada and the United Kingdom showed higher percentage gains of 81 and 58 percent, respectively. France, West Germany, Italy and Japan showed large percentage increases, again reflecting significant changes in the world marketing pattern.

Most significantly, Japan and West Germany are rapidly overtaking the United States in terms of per capita demand -- a significant development in light of considerable differences in GNP per capita.

Country	Steel - Per Capita Demand		
	1950 - lb.	1969 - lb.	Increase-Percent
United States	1,244	1,505	21
Canada	674	1,222	81
France	355	979	176
Germany, West	447	1,454	225
Italy	138	776	462
United Kingdom	612	966	58
Japan	111	1,327	1095


STEEL
1950 - 1969
Per Capita GNP - 1969 Dollars
Per Capita Demand - Pounds
United States
Canada
France
U.K.
West Germany
Italy
Japan
1,000
2,000
3,000
4,000
5,000
0
200
400
600
800
1,000
1,200
1,400
1,600
BEE 10x10

Zinc

Per Capita demand for zinc in the United States showed a small gain from 12.7 pounds in 1950 to 13.5 pounds in 1969, a 6-percent rise. United Kingdom also registered a small per capita gain of 1.0 pound for a 10-percent rise. On the other hand, per capita demand rose 53 percent in Canada, 110 percent in France, 200 percent in West Germany, 319 percent in Italy, and 821 percent in Japan. West Germany's per capita demand of 15.6 pounds exceeded that of the United States in 1969.

The trends would appear to have serious implications for U.S. primary zinc producers.

Country	Zinc - Per Capita Demand		
	1950 - lb.	1969 - lb.	Increase-Percent
United States	12.7	13.5	6
Canada	7.9	12.1	53
France	5.0	10.5	110
Germany, West	5.2	15.6	200
Italy	1.6	6.7	319
United Kingdom	10.5	11.5	10
Japan	1.4	12.9	821

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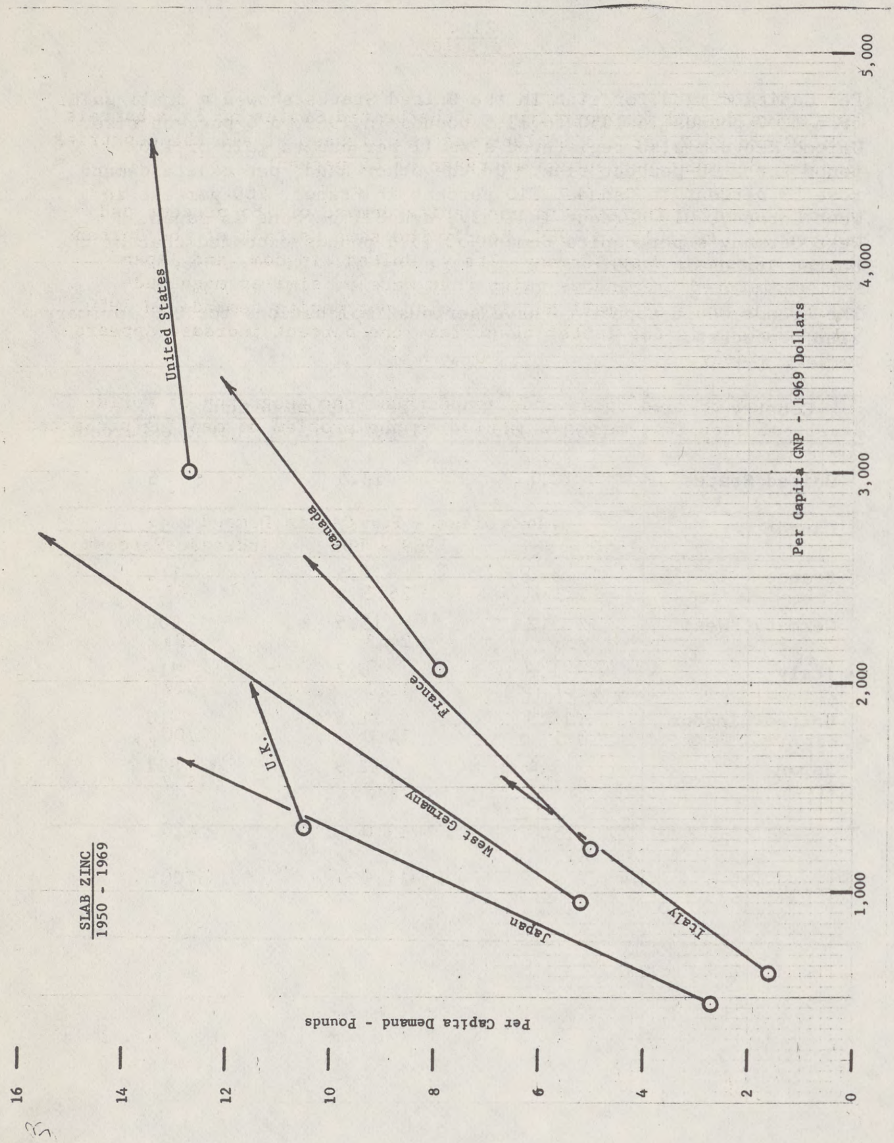

SLAB ZINC
1950 - 1969
Per Capita Demand - Pounds
0
2
4
6
8
10
12
14
16
Per Capita GNP - 1969 Dollars
1,000
2,000
3,000
4,000
5,000
United States
Canada
France
West Germany
U.K.
Japan
Italy

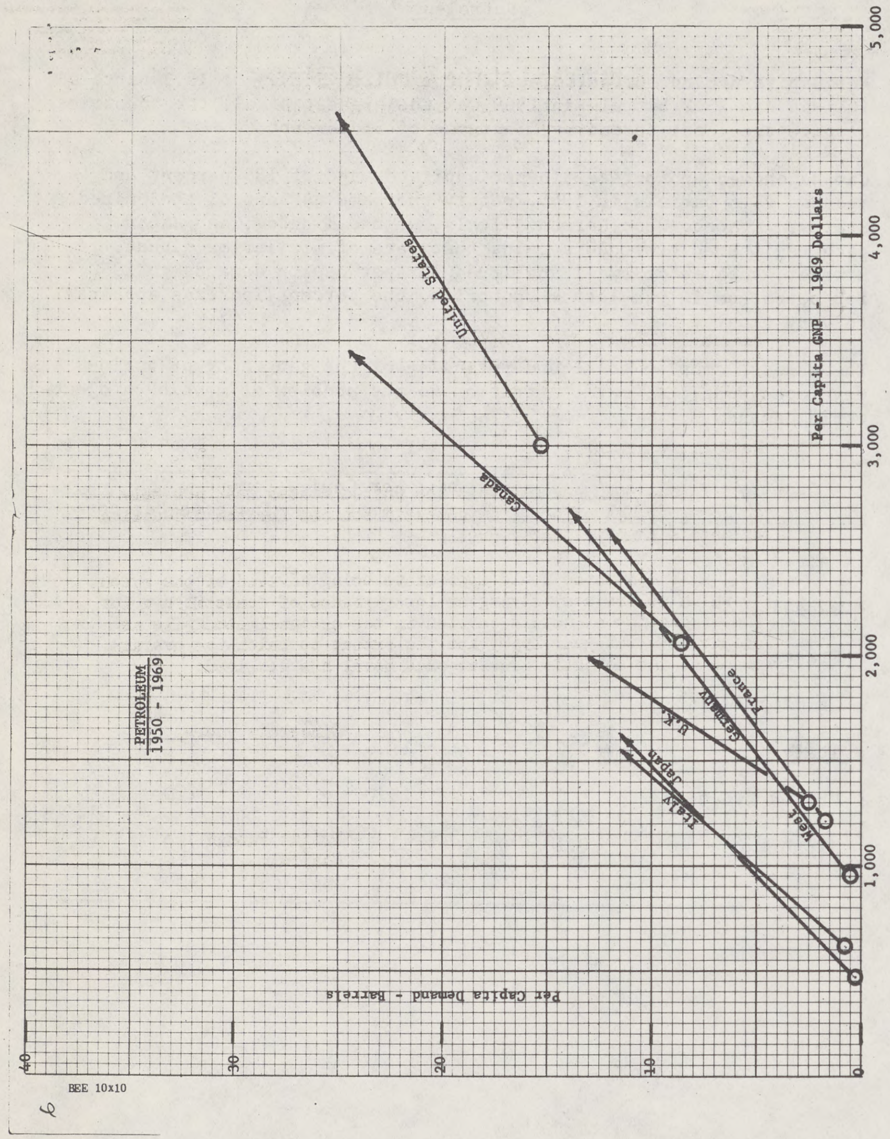
Petroleum

Per Capita demand for petroleum in the United States of 15.3 barrels in 1950 and 25.2 barrels in 1969 was the highest of all the countries despite the least percentage increase of 65 percent.

Canada showed an increase in per capita demand of 185 percent and reached 24.5 barrels in 1969, nearly the same as that of the United States. France, West Germany, Italy, United Kingdom, and Japan each registered tremendous gains that were of similar magnitude. However, because of small and irregular per capita demands in 1950 for petroleum in the latter countries, the percent increase appears to vary widely.

The trends, coupled to an understanding of the geography of world-developed supplies, merit attention to the problem of meeting projected world demands.

Country	Petroleum - Per Capita Demand		
	1950 - bbl	1969 - bbl	Increase-Percent
United States	15.3	25.2	65
Canada	8.6	24.5	185
France	1.7	12.1	612
Germany, West	0.5	14.0	2700
Italy	0.7	11.6	1557
United Kingdom	2.5	13.0	420
Japan	0.2	11.6	5700


PETROLEUM
1950 - 1969
Per Capita Demand - Barrels
Per Capita GNP - 1969 Dollars
0
10
20
30
40
1,000
2,000
3,000
4,000
5,000
United States
Canada
France
West Germany
U.K.
Japan
Italy
BEE 10x10

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Congress of the United States
JOINT COMMITTEE ON DEFENSE PRODUCTION
(CREATED PURSUANT TO PUBLIC LAW 774, 81ST CONGRESS)
WASHINGTON, D.C. 20510

June 16, 1971

Honorable Rogers C. B. Morton
The Secretary of the Interior
Department of the Interior
Washington, D. C. 20240

Dear Mr. Secretary:

It has been assumed that the United States must now rely on lower grades of ore from domestic sources for the production of metals than in past years.

This committee would appreciate being advised of the extent to which we are now relying on lower grades of domestic ore for the production of metals carried in the national stockpile as compared to the year 1950, and the extent to which the average grade of the domestic ore for each metal has declined.

Sincerely yours,

Wright Patman
Chairman

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

JUL 2 3 1971

Dear Mr. Patman:

In response to your letter of June 16, 1971, and as a result of conversations with members of my staff, we have compiled data comparing the grade of ore mined and the percent of demand supplied by domestic metal and mineral production in 1950 and 1969 shown in the enclosed table.

In addition to the depletion of higher grade deposits, ore mined for some materials such as bauxite, copper, iodine, molybdenum, titanium for nonmetal uses, tungsten, vanadium and zinc can be partly attributable to changing economics which permit processing lower grade material. The discovery of higher grade deposits has resulted in an increase in the grade of ore mined for lead. The grade of ore mined for mercury varies according to the market situation.

Sincerely yours,

Hollis M. Dole
Assistant Secretary

Honorable Wright Patman
Chairman, Joint Committee
on Defense Production
Washington, D. C. 20510

Enclosure

Comparisons for 1950 and 1969 of metals and minerals in the national stockpile for grade of ore mined and percent of demand supplied by domestic production.

Metals and minerals produced domestically

	Average grade of ore mined (percent unless otherwise noted) (estimated or calculated)		Percent of demand from primary supply by domestic production.	
	1950	1969	1950	1969
Aluminum (Bauxite)	25	22	34.5	9.8
Antimony	0.78	0.41	36.6	10.7
Beryllium	NA	NA	18.3	NA
Copper	0.89	0.60	60.1	91.1
Fluorine	16.4 1/	15.8	68.7	13.6
Graphite, Other	NA	NA	NA	NA
Iodine, parts per mil.	NA	38	72.2	15.1
Iridium oz.per.cu.yd.	NA	0.0012	32.3	5.8
Lead	2.6.	4.7	61.7	58.3
Manganese	NA	NA	23.1	7.1
Mercury	0.47	0.25	9.6	42.0
Molybdenum	0.25	0.22	141.4	174.2
Nickel	NA	1.4	0.9	10.4
Palladium, oz.per.cu.yd.	NA	0.000031	12.4	1.9
Platinum, oz.per.cu.yd.	NA	0.0065	6.9	2.8
Silver, oz./ton	18.0	19.6	31.5	42.5
Thorium oxide (monazite)	0.11	0.04	143.5	77.5

	Average grade of ore mined (percent unless otherwise noted) (estimated or calculated)		Percent of demand from primary supply by domestic production.	
	1950	1969	1950	1969
Titanium, non-metal	1.2-11	1.2-11	69.1	59.4
Tungsten	1.1	0.7	60.1	47.8
Vanadium	0.84	0.56	163.6	73.8
Zinc	5.5	3.9	60.3	36.8

Metals and minerals produced solely as byproducts (grade of ore not available)

	Average grade of ore (percent)		Percent of demand for primary supplied by domestic production.	
			1950	1969
Bismuth	NA	NA	62.5	38.8
Cadmium	NA	NA	49.5	32.5
Cobalt	NA	NA	9.8	5.3

Metals and minerals for which there is no or insignificant domestic production.

	Average grade of ore (percent)		Percent of demand for primary supplied by domestic production	
	1950	1969	1950	1969
Asbestos Amosite	0	0	0	0
Asbestos Chrysotile (stockpile grade)	0	0	0	0
Chromium	NA	0	1	0
Columbium	0	0	0	0

	Average grade of ore (percent)		Percent of demand for primary supplied by domestic production	
	1950	1969	1950	1969
Diamond Bort, Natural	0	0	0	0
Diamond Stores, Natural	0	0	0	0
Graphite Natural Ceylon	0	0	0	0
Graphite Natural Malagasy	0	0	0	0
Mica (stockpile grade)	NA	0	1	0
Quartz Crystal, Natural	0	0	0	0
Sapphire & Ruby, Natural	0	0	0	0
Talc, Steatite Block and Lump	0	0	0	0
Tantalum	0	0	0	0
Tin	1-2	1-2	1	1
Titanium Metal	0	0	0	0

NA - Not available

1/ Data for grade of ore not available until 1956.

Supplemental Notes

Aluminum - Average grades of bauxite mined based on estimates by Bureau of Mines and U. S. Geological Survey.

Antimony - Ore grades supplied by Sunshine Mining Co., Idaho, the leading producer. Other antimony is recovered as a byproduct of base metal processing.

Asbestos, Amosite - Mined only in the Republic of South Africa.

Asbestos, Chrysotile - Domestic stockpile grade fiber is available only from Arizona. An estimated 3,200 short tons might have been acceptable in 1969. Other data are unavailable but virtually all of stockpile or better grade probably is supplied from abroad.

Beryllium - A very small part of U. S. requirements supplied in the past partly from beryl in pegmatites, some of which were known to average 0.6 percent beryllium. Beryl also was recovered as a byproduct with pegmatite minerals. Bertrandite ores have supplanted beryl as a domestic source of beryllium thus virtually relieving United States of foreign dependence, as indicated for 1969. Data for 1969 are withheld since they are company confidential.

Bismuth - Byproduct only, grades not available.

Cadmium - Byproduct only, grades not available.

Chromium - Some concentrates produced in 1950; no domestic mine production in 1969.

Cobalt - Byproduct only, grades not available.

Columbium - No domestic production.

Copper - 1950 demand included deliveries to the Government stockpile.

Diamond - All natural diamonds for industrial use have been imported. Since 1954, manufactured diamonds have become competitive with natural diamond bort, 35 mesh and finer. A 1969 survey by the Department of Commerce indicated manufactured diamond supplies about 57 percent of the industrial diamond demand.

Fluorine - Grade data for domestic ores not available until 1956 when grade averaged 16.4 percent fluorine.

Graphite - Ceylon and Malagasy graphites are imported from those countries. The bulk of U. S. requirements for graphite are currently met by domestic manufactured graphite rather than by natural graphite, which has been largely displaced. Data for domestic production of Graphite, Natural, Other are withheld since they are company confidential.

Iodine - Is produced from brines. Concentrations were probably higher in 1950 than the average 38 parts per million in 1969; improved technology has permitted processing more dilute solutions in recent years.

Iridium - Grade applies to Alaskan placer production by dredging. Iridium accompanies platinum to the extent of about 20 percent of the total. Demand in 1950 was estimated from 1951 data.

Lead - Grades apply to lead ores only.

Manganese - Ores providing primary supply of manganese are classified, as follows, with average grades: Manganese ore, 1950, - 56 percent; 1969 - 48 percent. Ferruginous manganese ore, 1950 - 14.2 percent; 1969 - 13.2 percent. Manganiferous iron ore, 1950 - 6.1 percent; 1969 - 7.1 percent. Low grade manganiferous iron ore, 1950 - 2 to 5 percent; 1969 - 2 to 5 percent.

Mercury - 1950 was a year of exceptionally low production.

Mica - Although domestic resources of muscovite mica exist, grades produced have often failed to meet stockpile requirements. Only block mica has been produced, partly because of the high cost of labor to scale film and produce splittings. There are no domestic deposits of phlogopite sheet mica. Substitutes are replacing strategic grades of sheet mica for many purposes.

Molybdenum - A surplus is produced and contributes to exports. Ore reserves are very large. Some production is a co-product of copper mining.

Nickel - Byproduct metal in 1950.

Palladium - Grade applies to Alaskan placer production by dredging of gravels. Data not available for 1950.

Platinum - Grade applies to Alaskan placer production by dredging of gravels. Data not available for 1950.

Quartz Crystal - Consumers of natural quartz crystal have been totally dependent on imports. However, commercial development of synthetic