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STANDARD REFERENCE DATA AUTHORIZATION

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HEARINGS BEFORE THE SUBCOMMITTEE ON SCIENCE, RESEARCH, AND DEVELOPMENT OF THE COMMITTEE ON SCIENCE AND ASTRONAUTICS U.S. HOUSE OF REPRESENTATIVES NINETY-FIRST CONGRESS

FIRST SESSION

ON

H.R. 4284

MAY 1, 1969

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May 1, 1969:

Dr. Allen V. Astin, Director, National Bureau of Standards, accompanied by: Dr. Edward L. Brady, Associate Director for Information Programs, National Bureau of Standards, and Dr. Paul C. Cross, vice president for research, Carnegie-Mellon University, Mellon Institute (member of NBS Statutory Visiting Committee) --	Page 3
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(III)

STANDARD REFERENCE DATA AUTHORIZATION

THURSDAY, MAY 1, 1969

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SUBCOMMITTEE ON SCIENCE, RESEARCH, AND DEVELOPMENT,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10:12 a.m., in room 2325, Rayburn House Office Building, Hon. Emilio Q. Daddario (chairman of the subcommittee) presiding.

Mr. DADDARIO. This meeting will come to order.

The subcommittee this morning has before it the authorization for the Standard Reference Data Program which the National Bureau of Standards supervises and which authorization stems from a bill this subcommittee previously handled. We recognize the importance of this work to the country, and are pleased to have as our witnesses today Dr. Allen V. Astin, who is the Director of the National Bureau of Standards, Dr. Edward L. Brady, Associate Director for Information Programs, and Dr. Paul Cross, who is vice president for research at Carnegie-Mellon University and who is a member of the NBS Statutory Visiting Committee.

(H.R. 4284 follows:)

[H.R. 4284, 91st Cong., first sess.]

A BILL To authorize appropriations to carry out the Standard Reference Data Act

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That there are hereby authorized to be appropriated to the Department of Commerce such sums as may be necessary for the fiscal years 1970 and 1971, but not to exceed a total of \$6,000,000, and such sums as may be necessary for succeeding fiscal years, to carry out the purposes of the Standard Reference Data Act (Public Law 90-396; 82 Stat. 339).

Mr. DADDARIO. Dr. Astin, we are pleased to have you here and will allow you to proceed in any way you would like.

(The biographies of Drs. Astin, Brady, and Cross follow:)

DR. A. V. ASTIN, DIRECTOR OF THE NATIONAL BUREAU OF STANDARDS

Dr. Astin was born in Salt Lake City, Utah, in 1904. He received his bachelor's degree in physics from the University of Utah in 1925 and his Ph. D. from New York University in 1928. From 1928 to 1930 he was a National Research Council Fellow at Johns Hopkins University.

Dr. Astin joined the staff of the National Bureau of Standards in 1932. His principal fields of work included precision electrical measurements, the development of early radio telemetering techniques, and during World War II the development of proximity fuzes. He was named Chief of the Bureau's Ordnance Develop-

ment Division in 1948. The President appointed him as the fifth Director of the National Bureau of Standards May 31, 1952.

Honors and awards include the following: Gold Medal Exceptional Service Award, Department of Commerce; honorary Doctor of Science Degrees from Lehigh University, George Washington University, New York University; the National Civil Service League Award; the Rockefeller Public Service Award; the Scott Gold Medal of the American Ordnance Association; the Award to Executives of the American Society for Testing and Materials; and the Distinguished Alumni Award of the University of Utah. Dr. Astin is a Fellow of the American Physical Society, the Institute of Electrical and Electronic Engineers; an honorary life member of the Instrument Society of America, the Standards Engineers Society, Inc., and the American Dental Association. He is a member of the American Philosophical Society, American Academy of Arts and Sciences, and the National Academy of Sciences. He serves as the U.S. member on the International Committee of Weights and Measures and as Chairman of the Committee on Federal Laboratories of the Federal Council for Science and Technology.

**DR. EDWARD L. BRADY, ASSOCIATE DIRECTOR FOR INFORMATION PROGRAMS,
NATIONAL BUREAU OF STANDARDS**

Dr. Edward L. Brady was born in Charleston, South Carolina, on April 21, 1919. He was educated at the University of California at Los Angeles (B.A. and M.A. in chemistry) and Massachusetts Institute of Technology (Ph. D. in physical chemistry).

Dr. Brady began his professional career in 1942 as a Research Assistant at the University of Chicago's Metallurgy Laboratory. From 1943-46 he was a Research Associate at Clinton Labs, Oak Ridge, Tennessee (now Oak Ridge National Laboratory). From Oak Ridge he went to M.I.T. where he held a similar position for two years. During the years 1948-59 he carried out a variety of assignments involving atomic energy for the General Electric Company. For two years during this period he was on a leave of absence to serve as U.S. Atomic Energy Commission Representative to the United Kingdom, stationed in London, England. In July 1959, Dr. Brady became the Senior Scientific Advisor for the United States Mission to the International Atomic Energy Agency in Vienna, Austria. He left Vienna in the fall of 1961 to become Assistant Chairman of the Chemistry Department in the General Atomic Division of General Dynamics Corporation.

Dr. Brady came to NBS in 1963 to serve as Chief of the Office of Standard Reference Data. In this position he was responsible for directing the National Standard Reference Data System (NSRDS), which was established at the National Bureau of Standards in June of 1963 by the Office of Science and Technology acting on a recommendation of the Federal Council for Science and Technology. The NSRDS program provides critically evaluated data in the physical sciences to the scientific community.

In December of 1968 NBS reorganized its technical and public information programs to combine all of the major NBS units which gather, analyze, publish, and distribute scientific and technical information under an Associate Director for Information Programs. Dr. Brady assumed this position upon its creation, and now directs the activities of the Office of Standard Reference Data, the Clearinghouse for Federal Scientific and Technical Information, the Office of Technical Information and Publications, the Library Division, the Office of Public Information, and the Office of International Relations.

Throughout his scientific career, Dr. Brady has specialized in physical chemistry and radiochemistry. He has authored many publications on various radiochemical and physical-chemical topics. He is a member of the American Chemical Society, the American Nuclear Society, the American Physical Society, the American Association for the Advancement of Science, and the Cosmos Club.

Dr. Brady and his wife, the former Evelyn Padway, reside in Washington, D.C.

DR. PAUL CROSS, VICE PRESIDENT FOR RESEARCH, CARNEGIE-MELLON UNIVERSITY, MELLON INSTITUTE (MEMBER OF NBS STATUTORY VISITING COMMITTEE)

Cross, Dr. Paul C(lifford), Mellon Institute, 4400 Fifth Ave, Pittsburgh 13, Pa. Physical Chemistry. Bruin, Pa. July 19, 07; m. 32; c. 4. B.S, Geneva Col, 28; M.S, Wisconsin, 30, Ph. D. (phys. chem), 32; M.S, Brown, 42; hon. Sc.D, Waynesburg Col, 63; hon. Sc.D, Geneva Col, 63. Alumni Res. Corp. fel, Wisconsin, 32-33; Nat. Res. Coun. fel, Calif. Inst. Tech, 33-35; Carnegie Found.

fel, Stanford, 35-36, asst. prof. chem. 36-38; assoc. prof. Brown, 38-42, prof, 42-49, dir, Metcalf res. lab, 46-49, chmn. dept, chem, 47-49, prof. chem. & head dept, Washington (Seattle), 49-61; Pres, Chief Exec. Officer & Trustee, Mellon Inst, 61- Adj. prof, Pittsburgh, 62- ; summers, lectr, Harvard, 41; 46, Wisconsin, 52; dep. res. dir, underwater explosives res. lab, Woods Hole Oceanog. Inst, 43-44, res. dir, 44-46; mem. staff, MPC Corp, Pa. Mem. citizen's Sponsoring cmt, Allegheny Conf. Commun. Develop, 62- ; adv. cmt, Health Res. & Serv. Found. United Fund. With U.S.N; U.S.A.A.F, 44. AAAS; fel. Phys. Soc; fel. Am. Acad; fel. N.Y. Acad; Chem. Soc; Newcomen Soc. The theory of infrared and raman vibrational spectra; molecular vib-rotors; theory and interpretation of high resolution infrared spectra; spectroscopy and structure of molecules and free radicals; thermodynamics; photochemistry; explosion phenomena.

STATEMENT OF DR. ALLEN V. ASTIN, DIRECTOR, NATIONAL BUREAU OF STANDARDS, ACCOMPANIED BY DR. EDWARD L. BRADY, ASSOCIATE DIRECTOR FOR INFORMATION PROGRAMS, NATIONAL BUREAU OF STANDARDS, AND DR. PAUL C. CROSS, VICE PRESIDENT FOR RESEARCH, CARNEGIE-MELLON UNIVERSITY, MELLON INSTITUTE, MEMBER OF NBS STATUTORY VISITING COMMITTEE

Dr. ASTIN. Thank you very much, Mr. Chairman.

I would like to say a few words, by way of introduction, and then have Dr. Brady present the primary justification.

Vannevar Bush, one of this country's most distinguished scientists and engineers, wrote in the preface to the history of the National Bureau of Standards the following:

If men are to accomplish together anything useful whatever, they must, above all, be able to understand one another. That is the basic reason for a National Bureau of Standards.

One of the most sophisticated activities we have, which contributes to the understanding and communication among scientists and engineers, is the Standard Reference Data program. This program seeks to distill from the world's scientific and technical output the quantitative information, which is used to describe the properties of matter and materials. These data are evaluated, inconsistencies among data, from different sources are reconciled, and confidence limits are established for the numbers that are extracted. They are then made available in ready reference form, to facilitate the work of scientists and engineers everywhere.

In my judgment, there is no activity that can so significantly affect the efficiency and effectiveness of the work of scientists and engineers. This is a program which is completely nonglamorous but it requires great skill and dedication.

It is my judgment, that a properly implemented Standard Reference Data program would profoundly affect the efficiency of this Nation's \$16 billion annual expenditures for scientific research and development.

Now, the man who organized our Standard Reference Data program is Dr. Edward Brady. He came to organize this activity 5 or 6 years ago and he developed it to its present stage, designed the way it should be operated, and did a very fine job in getting it going.

We moved him to a new position of associate director for information programs at the beginning of this calendar year.

The other gentleman with me, Dr. Paul Cross, has been a member of our Visiting Committee for the past 5 years. This is a committee

established by law to advise the Secretary of Commerce on the efficiency of the Bureau's programs.

Dr. Cross is a distinguished physical chemist as well as a research administrator and has been closely associated with our Standard Reference Data program from the beginning.

Dr. Brady has a formal statement which he would now like to give in justification of our proposal.

Mr. DADDARIO. Dr. Brady.

Dr. BRADY. Thank you, and Dr. Astin.

Mr. Chairman and members of the subcommittee, we are very pleased to have the opportunity to appear before this subcommittee today and to report to you on the progress that we have made in developing a National Standard Reference Data system. This progress is substantial, but the tasks that remain ahead are even larger. The basic framework for the NSRDS is firmly established. It consists of a coordinated network of data analysis centers, each concentrating on a well-defined subject, now producing a steady stream of data compilations, critical reviews, and bibliographies. The National Bureau of Standards has become recognized as the institution in the Government, from which American scientists and engineers can obtain compilations of high quality data on the properties of substances. Cooperation with related activities in other countries is increasing; both governmental and nongovernmental mechanisms have been established to promote such cooperation. Nevertheless, we have proceeded only a short way down the trail to our goal. We know where we want to go from here, and we hope that this subcommittee will give us a big push, to help us on our way.

Let me first review briefly the objectives of the National Standard Reference Data system. Basically, there are two: first, to provide critically evaluated data to scientists and engineers throughout the country, who need them in the everyday conduct of their work, and second, to upgrade both the quality of experimental practice in laboratories and the reporting of experimental measurements in the public literature. I would now like to discuss each of these goals in more detail.

Mr. DADDARIO. Dr. Brady, before you go on, can you identify the number of scientists and engineers who are the users of this information?

Dr. BRADY. We made a little survey, Mr. Daddario, aided by the American Chemical Society, and found that approximately 75 percent of the respondents claimed that they needed data of this kind in the everyday conduct of their research activities.

Now, if we can extrapolate a figure of about 75 percent to all of the scientists and engineers throughout the country, which total about a million and a half, this would be of the order of a million or more persons throughout the country, who would use data of this kind. I think that is a little high, actually, but there are probably three-quarters of a million potential customers, the scientists, and engineers of the country who are the users.

Mr. DADDARIO. You are saying that the Chemical Society, in compiling this information, gives you a yardstick, then you downgrade that somewhat for other user groups, so that rather than being 75 percent, it is somewhat less but still a formidable figure?

Dr. BRADY. Indeed.

Since the meaning of the word "data" depends upon who uses it, perhaps a definition now, would be timely. The word "data" in the standard reference data system means the results of quantitative measurements of the physical and chemical properties of substances. Such a property might be, for example, the fraction of light of a definite wavelength absorbed by a specific amount of a substance, or the amount of energy released when chemical elements combine to form a new compound, or the ability of a substance to conduct electricity or heat under certain well-defined conditions.

Data such as these are used by most engineers and scientists every day. For example, in order to calculate how much cooling fluid is required, a nuclear powerplant designer must know how rapidly heat is conducted through the coating of the uranium fuel element in the reactor core, how rapidly heat is conducted through the shielding material, and how rapidly heat is transferred through the material of the steam generator. For another example, designers of the Saturn rocket had to know accurately how much heat is given off, when oxygen combines with hydrogen in order to calculate the thrust of the rocket. The Apollo capsule designer had to know how much of the sun's energy is reflected by the capsule's external surface in order to determine how to maintain proper temperature control in the cabin. A chemical engineer must know the aqueous solubilities of the waste materials from a plant in order to control pollution in the surrounding area. This list of examples could be multiplied many thousandfold.

The first place that a scientist or engineer looks for such data when he needs them is a handbook on his own bookshelf. Unfortunately, more often than not, the data that he seeks will not be there. Or, if it is there, its reliability is usually not known. If it is more than a few years old, its accuracy is likely to be unsatisfactory for modern requirements. The costs of using inaccurate data, though certainly enormous, are impossible to identify; they are manifested as inefficiencies throughout all of science and technology.

Mr. DADDARIO. Dr. Brady, as you demonstrate the relationship of dollar costs to the necessity of supporting a program of this kind, how do you see the savings? I recognize that this is a very tenuous estimate you could make, but it would be helpful to us.

Dr. BRADY. Yes, sir. There are three kinds of savings or benefits as we see them. First is the benefit of the saving in time, search time, of the individual scientist or engineer in looking through the great mass of accumulated literature to try to find a particular number that he wants. If it is not in a compilation, he has to search in the library and perhaps search through dozens or even hundreds of papers to locate a particular number. Then, when he finds it, he is not sure how good it is and he either has to make an evaluation, or call a friend who is a specialist to make the evaluation. So the saving of time in searching and evaluating is one important factor.

Another important factor is the use of better data. With data of known accuracy you can reduce tolerances in designs, you can have more confidence in theories that are based on the actual quantitative value of a particular number, you can use these better data to improve the rate of progress of science and engineering.

The third way, and I will come to this in more detail later, is by a generalized upgrading of the quality of experimental measurements in laboratories throughout the country and in the reporting of those measurements in the literature. I will go into some more detail on this point later.

Now, taking all of these into account, Mr. Daddario, we have made various estimates of the cost-benefit ratio that is obtained from a number of specific compilations that have been produced. These cost-benefit ratios range from estimates of about \$20 per each dollar spent on the program to the order of \$200 or so for each dollar spent. I think the estimate would have to be made on a case-by-case basis, in that fashion.

Mr. DADDARIO. Thank you.

Mr. MOSHER. Mr. Chairman.

Mr. DADDARIO. Yes, Mr. Mosher.

Mr. MOSHER. I am interested in Dr. Brady's statement that if the handbook is more than a few years old, its accuracy is likely to be unsatisfactory for modern requirements. I assume the implication there is, not that the phenomena have changed over the years, but that the technology by which the measurements are made has improved so much?

Dr. BRADY. Yes, sir.

Mr. MOSHER. That the measurements themselves in actuality are immutable or to some considerable degree immutable; in other words, nature doesn't change or the laws of nature don't change?

Dr. BRADY. Yes.

Mr. MOSHER. But the means by which you make these measurements is rapidly improving and therefore the handbook is old because of that reason.

Dr. BRADY. Indeed; yes, sir. And the requirements that are placed on the data are more stringent as science and technology progress. You need to know the data more accurately.

Mr. MOSHER. Based on today's technology, the handbooks that you are likely to be developing out of your program are going to have a longer life, a longer validity than the handbooks of a few years ago?

Dr. BRADY. Probably so, but the duration of validity depends on the field.

Mr. MOSHER. Of course.

Dr. BRADY. In some fields it might be as much as 20 years, and in others only 2 to 4 years.

Mr. DADDARIO. Once you get the program underway, it becomes an easier process to bring them up to date?

Dr. BRADY. Yes, sir.

Mr. DADDARIO. People know also how to handle that information, so that you have a double process. You bring it up to date easier, and people learn how to manage it more easily. It all is a part of the educational process, I would expect, through which research grows.

Dr. BRADY. Yes, sir; indeed.

Compilations of data, carefully evaluated by experts, are needed to minimize these inefficiencies. Such compilations are a normal instrument of technical progress. They are being prepared now and have been throughout the history of science and technology. I sometimes

use a photograph of Stonehenge to illustrate the antiquity of data compilations. However, science and technology are moving so rapidly these days that the individual personal initiatives traditionally responsible for compiling data have not been able to maintain pace with the rate of new data appearing in the literature. This is the basic reason why the Federal Council for Science and Technology several years ago called upon the National Bureau of Standards to organize and administer a coordinated effort to compile and evaluate the data immersed in the accumulated, and rapidly growing, world's literature. This was the birth of the National Standard Reference Data system.

The National Standard Reference Data system is conducted as a decentralized operation of nationwide scope with central coordination by NBS. It consists of a network of data analysis centers and related activities carried on in Government agencies, academic institutions, and nongovernmental laboratories. A data center is a group of technical specialists, supplemented by librarians, computer programmers, and other information scientists, who collect technical information in a carefully defined field, then index, abstract, and evaluate the material. The intellectual products of a data center, which demand critical judgment of the highest level of technical sophistication, consist of compilations of critically evaluated data, critical reviews of the state of quantitative knowledge in specialized areas, and computations of useful functions derived from experimental data. The NSRDS coordinates existing data evaluation and compilation activities into a systematic program, supplements and expands technical coverage when necessary, establishes standards for quality and for machine processing when required, and provides mechanisms for the distribution of the products. Within NBS, the Office of Standard Reference Data, under the leadership of Dr. David R. Lide, who is sitting here behind us, has operations responsibility for managing the program.

Mr. DADDARIO. Dr. Brady, could you provide for the record, without going into it in detail here, the way in which this coordinating mechanism works; what kind of an organization do you have to do this within NBS; and how it relates to other agencies within the government?

Dr. BRADY. Yes, sir. You want that supplied for the record?

Mr. DADDARIO. For the record, yes.

Dr. BRADY. Yes, sir.

(The information requested is as follows:)

For management purposes the scope of NSRDS is divided into seven technical program areas: nuclear data, atomic and molecular data, solid state data, thermodynamic and transport properties, chemical kinetics, colloid and surface properties, and mechanical properties. A program manager in the Office of Standard Reference Data is responsible for each of these areas. In addition to monitoring the existing NSRDS-supported data centers in his technical area, each program manager keeps abreast of developments in his field of specialty and recommends changes or additions to the program when appropriate. The program managers also maintain liaison with other agencies and private groups which support related data compilation activities.

A more formal mechanism for maintaining contact with the scientific and technical community is provided by the Advisory Panel in each program area. These panels are organized by the National Academy of Sciences-National Research Council, and they consist of experts drawn from universities and industrial laboratories throughout the country. The Advisory Panel for a given technical area meets every two to three years. In addition, ad hoc sub-panels are called to discuss problems in specialized fields. These panels are asked to advise

NSRDS in its program planning by setting general priorities, emphasizing fields in urgent need of attention, and recommending suitable individuals for specific data-compilation projects. In setting priorities the panels consider such factors as (a) the demand for critically evaluated data, (b) the ripeness of the field for compilations (i.e., whether measurement techniques are sufficiently stabilized that no dramatic changes in accuracy can be anticipated in the near future), and (c) the current state of compilation activities. Within the limits of its resources, the Office of Standard Reference Data attempts to implement the recommendations of the Advisory Panels by initiating new data centers, expanding existing centers, or in some cases by supplementing data centers already supported by other sources.

The coordination between the NSRDS program and the data compilation programs of other agencies is based in part on the close personal contacts between the respective office staffs. In the case of jointly funded data centers, a joint review is conducted at least annually. Proposals for new compilation projects which are submitted to the Atomic Energy Commission are routinely sent to the Office of Standard Reference Data for review. Similarly, proposals to the Office of Standard Reference Data which fall within the scope of interests of the AEC are sent to the appropriate Division of the AEC. With respect to the military agencies, OSRD has acted as technical monitor on several projects which were directly funded by DoD.

As an example of more formal coordination mechanisms, an Advisory Panel on Nuclear Data was convened by OSRD in November, 1968, to discuss serious problems in the compilation of nuclear data. The report of this panel has permitted the AEC, which still supports the bulk of the nuclear data activities, to plan its program more effectively.

Dr. BRADY. Since the program began in 1963, the many people working under the auspices of the National Standard Reference Data System have struggled valiantly to catch up. I am afraid, however, that we have not been able to reduce the stockpile of accumulated literature very much. Of course, we are not as far behind as we would have been if we had not started at all, but we have a very long way to go even to keep up, much less catch up. Some figures will show you the growing magnitude of the problem since 1963 when we began. I will illustrate by using statistics from the literature of chemistry and physics, where most of the data of concern to us appear. The table below shows the number of pages published in two of the principal journals published by the American Chemical Society and the total pages published in all American Chemical Society publications.

You see from the table, which I think you all have before you, that the literature output, that is the number of pages, has almost doubled since 1963.

GROWTH OF U.S. CHEMICAL LITERATURE

Year	Journals of American Chemical Society	Journals of Physical Chemistry	Total American Chemical Society publications
1963.....	4,236	2,769	17,486
1964.....	5,947	3,997	22,313
1965.....	6,037	4,544	23,647
1966.....	6,174	4,217	25,717
1967.....	7,416	4,800	26,940
1968.....	7,500	5,500	30,700

We have estimated that the output of quantitative data contained in those pages has more than doubled, since the science of chemistry grows more quantitative every day. There are some indications that the American output is leveling off, but the total world's output shows

no such indication. This is clearly revealed in figure 1, which is shown below and indicates the growth in the number of entries in the American Chemical Society's publication, Chemical Abstracts, the world's major abstract journal in the field of chemistry. In figure 2 are shown similar data for the field of physics. The American Institute of Physics publishes approximately 35 percent of the world's literature in physics; the journal, Physical Review, which is published for the American Physical Society publishes more original research reports than any other physics journal in the world. The abstract journal, Physics Abstracts, is published by the Institute of Electrical Engineers in the United Kingdom.

In the National Standard Reference Data System our present level of effort would be adequate, I estimate, to maintain currency with the literature output of 1953. The compilation effort of the entire rest of the world is approximately half the U.S. effort, but is growing rapidly.

You may well ask why, if the need is so desperate, more scientists and engineers do not divert their activities to these kinds of projects. The answer is that there is little glamour in this work, little glory in the publication of a compilation of critically evaluated data, and it is more fun to do experimental work in the laboratory. Our program springs from the conclusion that the social pressures on scientists are such that the evaluated data needs of society can be met only if funds are specifically designated for the purpose, adequate to do the job. We are asking you to authorize today resources to enable us to meet some of those needs.

Fig.1 GROWTH OF WORLD CHEMICAL LITERATURE

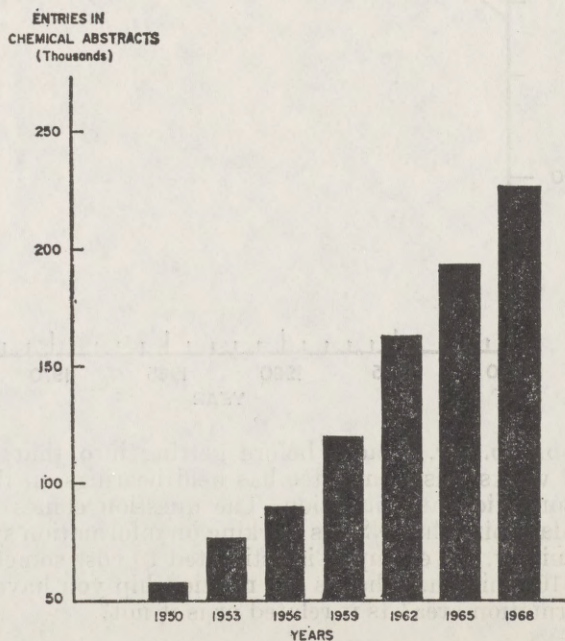
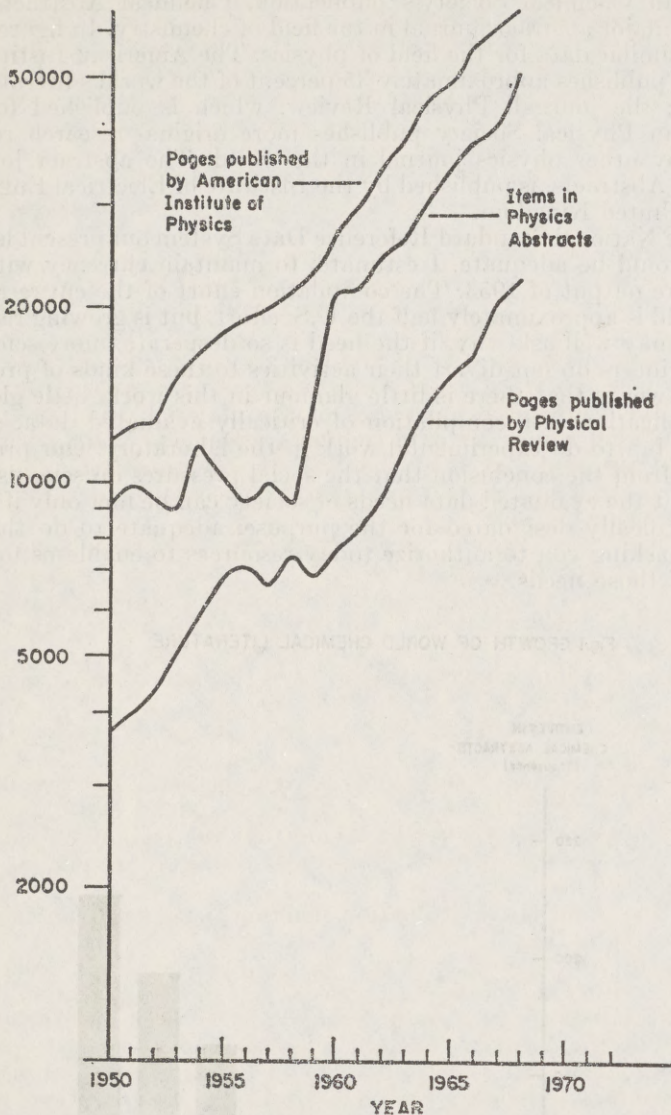


Fig.2 GROWTH IN PHYSICS LITERATURE



Mr. DADDARIO. Dr. Brady, before getting into that, during the last several weeks this committee has held hearings on the National Science Foundation authorization. The question comes to mind on this particular point that NSF is working on information systems. The one in chemistry, for example, is estimated to cost something in the nature of \$100 million. What is the relationship you have with them in this information area? Is it related or is it not?

Dr. BRADY. Very closely related indeed, Mr. Daddario. We have very close personal contact with the people in Dr. Adkinson's office, in the office of Science Information Service in NSF. We follow the work that they are supporting both in the information system in chemistry and the information system in physics. I, personally, and others in our office, meet quite regularly with the people in NSF. We consider that the system that they are developing and promoting is an integral part of the whole system. I should put it the other way around, I suppose. Our standard reference data system is an integral part of the international scientific information system, embracing chemistry, physics, biology, and so on.

The emphasis at present in the National Science Foundation program is on discipline-oriented systems. In chemistry they are supporting and working very closely with the Chemical Abstract Service, in the development of new services. The Chemical Abstract Service is going to be of immense value to all of the operators of the data centers that are part of the standard reference data program in providing to them an initial awareness of the material which contains data of the kind which our data centers are going to evaluate. None of the activities undertaken by the NSF at the present time include this most essential element of evaluation of the content of the material as part of their program.

We feature the evaluation function very strongly indeed. The other programs are concerned primarily with the processing of literature, the processing of abstracts, the indexing of material, while our program concentrates on the evaluation of the content of the literature.

Mr. DADDARIO. But the work that is being done by them does make this evaluation responsibility of yours that much easier, doesn't it? Doesn't it help you to catch up?

Dr. BRADY. It does indeed. It is a very important part of the whole system.

Mr. DADDARIO. Then how should we view the request that is being made here, together with the request of the National Science Foundation? Do you use those figures in saying that the amounts available will allow you to keep up with the present literature output for one year?

Dr. BRADY. That is the evaluation function that I am referring to.

Mr. DADDARIO. Yes, I understand that.

Dr. BRADY. And the effort of the National Science Foundation, in cooperation with the professional societies, has more application than to the immediate purpose of our program. We draw upon the work that they do to aid the national standard reference data program, but the two do not conflict with each other. They cooperate with each other. Much of the material that we produce from the standard reference data program will eventually go back into the literature and be part of the material which is handled by these systems. So the way I look at it is that our program is a complementary part of their program, or vice versa. The two complement each other.

Mr. DADDARIO. Dr. Brady, you put before us a very interesting idea when you tell us how little glamour there is to this work and how people would rather do other research. However, the standard reference data program is a very important program which our society needs, and you recommend that we authorize the funds.

Is this your feeling about the whole area of research in general? There are some areas that are more glamorous than others, but we need to do work in all of these fields, including the less glamorous.

Dr. BRADY. I think there is no doubt that there are areas of research and development that are considered to be much more glamorous than others and that there are fads in research, and people rush into a newly opened field and work at it at great speed and develop it and then after a while it becomes well worked over and much less glamorous.

And I think that there is a great deal of effort that goes into some of the very popular fields that could derive great benefits, indeed, from a systematic program of the kind that we are undertaking. We suggest to you, sir, that this kind of program undertaken comprehensively would make these popular areas of research more effective, that the investment that goes into those areas would be better spent if behind them, supplying the critical data that they need, is a systematic program of the kind that we operate.

Mr. DADDARIO. Do you have any comment on that, Dr. Astin?

Dr. ASTIN. I would agree with Dr. Brady's remarks. I feel that one of the best ways to bring better balance between the expenditures for glamorous activities and the less glamorous but usually more basic activities is the establishment of overall national programs such as the standard reference data program.

Mr. DADDARIO. How do you look at this, Dr. Cross?

Dr. CROSS. Well, I approve of what Dr. Brady said. I would like to add that in my contact with the various committees that have been brought together on this problem, they have done a remarkable job of persuading real headline scientists in the different areas to take on this work as a part-time effort. I think this is absolutely essential. You can't get a top scientist to drop everything he is doing and do this full time. And I think one of the strong features of this program is that by enlisting people both within and without the Bureau of Standards, they have in each field obtained some of the very top men. They have a conscience, and they realize the importance of the program and are willing to put part of their time on it.

Mr. DADDARIO. Then you appeal to that conscience by having the funds available so that on a part-time basis they can see the possibility of generating this kind of a system.

Dr. CROSS. They can see the benefit to them by putting a little effort in this area.

Mr. MOSHER. You are saying that this enterprise encourages coordination and teamwork in the whole scientific community.

Dr. CROSS. Right.

Dr. BRADY. Yes.

Mr. MOSHER. That the work that is done here on this sort of thing is a little bit like the work that linemen do on a football team.

Dr. CROSS. That is right.

Mr. MOSHER. They provide the blocking.

Dr. CROSS. Yes.

Mr. MOSHER. The means by which the headliners, the boys that throw the forward passes, do their job?

Dr. BRADY. It is a good analogy.

Mr. MOSHER. Of course, our chairman was one of the football headliners at one time and I am sure he agrees.

Mr. DADDARIO. These days some of the linemen are getting pretty well paid. [Laughter.]

Dr. BRADY. Now let us consider the second objective that I mentioned earlier—that of upgrading the quality of experimental work done throughout the country. In some of the earliest written material on the standard reference data program, the improvement of the quality of measurement throughout the Nation's laboratories was stated to be one of the benefits to be obtained from the program. Such improvement comes about because the systematic evaluation process reveals sources of uncertainty in laboratory measurement techniques and, also, aids in determining the comparative merits of different methods of measurement. If experimentalists are not using adequate techniques or if they are not making an adequate statistical analysis of their data, they soon learn about it.

This aspect of the program was not strongly emphasized because we could not determine in advance how important it was going to be. Experience in the operation of data centers over the past several years has demonstrated that this effect may well turn out to be equal in importance to the availability of evaluated data. I am confident that it will not come as a great shock or disillusionment to the members of this subcommittee to learn that scientists do not always do the right thing in the laboratory, nor do they always report their work properly. The NSRDS data centers are beginning to get estimates of the fraction of the measurements in their special fields that are reported with sufficient evidence of good technique to be really worth evaluating for other people to use in the future. The figures range from 25 percent to 75 percent.

Mr. MOSHER. Mr. Chairman.

Mr. DADDARIO. Yes, Mr. Mosher.

Mr. MOSHER. I am interested in this sentence. If expert analysts are not using adequate techniques or if they are not making adequate statistical analyses of their data, they soon learn about it. Now, how do they soon learn about it?

Dr. BRADY. The people who are working in the data centers try to maintain close personal contact with the people in the laboratories, and in many of these fields our data center people know three-quarters or more of the people who are really active in their field. They see them at meetings, they visit them in their laboratories, and they discuss their findings. And, again, when the evaluated data are published, if an expert analyst finds that his input data are not included for some reason he is going to want to know why. Thus, he is going to have some interaction with the data evaluators.

Mr. MOSHER. This mechanism of interaction is largely a personal and informal arrangement, largely?

Dr. BRADY. Yes.

Mr. MOSHER. There is no means by which someone is held up to public scorn in the scientific community or anything like that?

Dr. BRADY. No, sir. It is the informal personal contact through meetings, seminars, visits, or telephone conversations.

Mr. MOSHER. You are suggesting that this is an effective mechanism?

Dr. BRADY. I think it is a very effective mechanism, indeed, Mr. Mosher.

Mr. DADDARIO. Dr. Brady, when you talk about data "really worth evaluating," what do you mean by that?

Dr. BRADY. I indicated that the NSRDS data centers are beginning to get estimates of the fraction of the measurements in their special fields that are reported with sufficient evidence of good technique to be really worth evaluating for other people to use in the future, and the figures range from 25 percent to 75 percent.

Now, in saying that, I don't mean to imply, Mr. Daddario, that only 25 to 75 percent of the research reported in the literature is worth doing at all. Many of the data that are immersed in the literature were obtained to illustrate a particular point, to obtain a qualitative indication or something of that kind. Now, with a little additional effort and attention paid to more of the details of the measurement, this measurement could be made more quantitative so that it would become useful to a much larger group of scientists.

Mr. DADDARIO. I see.

Mr. CABELL. I am not trying to draw any odious comparisons here, but merely as a matter of information, is the National Science Foundation as meticulous in checking the authenticity and the validity of the papers and the work which they publish as you indicate you are?

Dr. BRADY. They do not, in general, support work of the compilation and evaluation type. They support primarily the original experimental investigation or theoretical investigation. This sort of work is behind the literature that the people working in our data centers review to come out with their compilations of evaluated data.

Mr. CABELL. Would it be accurate to say, then, that you screen more carefully this work prior to your publication of it and indexing of it?

Dr. BRADY. I would like to put it somewhat differently.

Mr. CABELL. All right.

Dr. BRADY. Their work provides the basic measurements, the raw material, in a sense, for the overall critical comparison that the people in our centers make. The people in our centers will compare the work of a particular man in a laboratory at the University of Minnesota, say, with results from other universities, and putting these all together, will then make a critical comparison and decide which of the values, of all that have been reported for a particular property, is the most likely to be correct. They will also establish limits of uncertainty. So our work is sort of a compression and a distillation of the total great mass of the original research literature that is published, much of it sponsored by the National Science Foundation.

Mr. CABELL. Then I take it that your work is more accurately the finished product of this research?

Dr. BRADY. Yes, at least as far as the numerical data are concerned.

Mr. CABELL. And it is more accurate and is more dependable as a reference source?

Dr. BRADY. We consider it more dependable as a reference source, yes. And some people do consider that the compilations and critical reviews that are being produced by our data centers are really the material that most other scientists and engineers are going to use eventually rather than the original literature. They will go back to the

original research report only if they are specializing in that field themselves and will want to know all of the details of the experiment. But in general the evaluations and summaries that our centers produce will probably be used by the majority of people who require data in the future.

Dr. ASTIN. May I try and add a sentence or two to clarify this point?

To an appreciable extent the critical evaluation functions of the scientific and technical data is the final phase in communication of scientific research. That is, the primary phase is publication of research results in the literature. The final phase is the evaluation of those results, the extracting of the significant numbers and then making them available in ready reference form. So it is just one step further in the total communication process.

Mr. CABELL. Would you say that they were the primary producers of this material from which then you do your evaluations?

Dr. ASTIN. Yes. Dr. Brady mentioned this point.

Mr. CABELL. Yes, but you need what they are doing for you to pick it up and complete the process, am I correct in that?

Dr. ASTIN. The scientific publications supported by the National Science Foundation and others are the raw material with which we deal.

Mr. CABELL. That is what I wanted to clarify.

Dr. ASTIN. Yes, sir.

Mr. CABELL. To see if it was a succession rather than a duplication.

Dr. ASTIN. No.

Dr. CROSS. May I also add a thought to that? I think the NSF program, not the research program now, but their information retrieval program, is intended to collect and codify the total scientific literature so they can put it into a computer. Now the computer can only feed out what is put in. It can't evaluate the information. Now it is very important to have this retrieval system, but the standard reference data program is doing the evaluation. I think the other involves no evaluation whatsoever—is that an overstatement?

Dr. BRADY. The NSF program includes evaluation of the general quality of the research, but not of specific data resulting from it.

Mr. CABELL. I am not trying to start a competitive situation there, but I was just trying to clarify the process through which this information went. Thank you.

Mr. DADDARIO. It is not quite fair to say that NSF information program is not evaluative. It depends upon the quality of the researcher and on what has been done. But you are talking about the next phase, where you extract that and you come to a further judgment.

Dr. BRADY. Yes, that is right.

Dr. CROSS. But the abstract journals really collect the totality of the literature and the individual has to do his own evaluation or trust some organization like NSRDS to have done it for him.

Mr. DADDARIO. Dr. Brady.

Dr. BRADY. We are learning what is required in a publication in order that a scientist or engineer who wishes to use a measurement result in the future may have confidence that it was made with adequate consideration of errors and sources of uncertainty.

Let me use an illustration taken from the experience of the Atomic Collision Cross Section Data Center operated by the National Bureau of Standards in Boulder, Colo. Under the auspices of this Center, a critical review was carried out of experimental data on the ionization of atoms when hit by electrons.

The results have been discussed by Dr. L. M. Branscomb, Director of the Joint Institute for Laboratory Astrophysics at the University of Colorado, in a recent paper. (L. M. Branscomb, "Is the Literature Worth Reviewing?", *Scientific Research*, pp. 49-56, May 27, 1968.)

He reports:

"The authors of this review first set out to analyze the basic experimental methods used. For each type of apparatus used they developed a set of specific criteria that had to be satisfied before one could state that a meaningful measurement had been made.

"When they compared the papers with the criteria, they found that only 10 percent of the papers in the collection contained even the most rudimentary evidence concerning the essential questions.

"Some papers fail to mention any precautions to prevent (or measure) secondary emission from the electron beam collector, thus nullifying the measurement of the electron current. Others failed to show that the path length of the electrons in the ionizing region was defined.

"Many failed to demonstrate a meaningful measurement of the target gas density. Of the 30-odd measurements of the helium cross section, only six of the papers could be evaluated in terms of the criteria established."

The conclusion of the paper is: "The rare gas cross sections are generally regarded as well known; the data presented here indicate that this opinion is not well founded unless one considers 20 percent to 25 percent as a small uncertainty."

Let me interject here that for some purposes 20 or 25 percent is a small uncertainty, but it certainly is not a highly precise measurement.

Branscomb further goes on to say:

"It seems likely that about 1,500 papers will be written in 1967-1971 containing reports of cross sections for electron collisions. These will cost somebody about \$30,000 apiece, or about \$45 million. Many of the papers will surely have value, even if they contain no reference data that can be critically evaluated; their primary purpose may have been altogether different, so the cost of the data quoted is relatively small.

"But to the extent that the work has a measurement of such cross sections as its primary purpose a substantial part of the \$45 million might be saved. How? Simply by not doing the work at all unless it is written up in such a way that it can be evaluated, and therefore become useful."

That is what I meant earlier when I said that the data may be incidental to the primary purpose of the paper. The situation just described is undoubtedly more dramatic in the particular field of investigation being discussed but similar, though less serious, situations certainly exist in other fields. Infrared spectroscopy is one; criteria for infrared measurements developed at the initiation of one of our projects are now being adopted (after slight modification by the appropriate international scientific unions) by analytical laboratories all over the world.

We are confident that in all of the fields in which the national standard reference data system is active, an enhanced rate of progress toward meaningful measurement is occurring.

Critical evaluations by NSRDS centers also provide guidance for the experimental programs of the groups in which they are located. You may recall that one of our basic principles of operation is that the data evaluation group must be closely associated with an active experimental or theoretical group in its field, and therefore it must be located in a laboratory environment rather than in a scientific information or library environment.

The laboratory director responsible for both data evaluation and experimental measurement programs soon learns to take advantage of the findings of the analysis group; he improves his experimental techniques and he has more information on what substances and what properties it is useful to measure.

From the foregoing discussion we conclude, therefore, that the output of the National Standard Reference Data system has both a tangible and an intangible component—tangible in the form of data compilations, critical reviews, and related publications, and intangible in the form of an advancement of the quality of experimental measurement throughout the country.

This output comes from approximately 25 data analysis centers wholly or partially funded by the Office of Standard Reference Data at NBS, plus another dozen or so centers funded by other agencies with which close contact is maintained. I have brought with me a few samples of our tangible output—that is, publications—for the subcommittee to examine.

And each of you, I believe, has a list of the publications that we have produced.

The Standard Reference Data Act, Public Law 90-396, gave additional authorities to the Secretary of Commerce, thereby providing new flexibility in the standard reference data system. This act enables us to operate a publication and distribution program making use of the combined capabilities of the Government Printing Office, the Clearinghouse for Federal Scientific and Technical Information, commercial publishing houses, and professional society publications.

In order to take advantage of the authority that we now have to recover a portion of the cost of operation of the program, we shall enter into arrangements with commercial publishers under which a fraction of the selling price of NSRDS publications will be returned to the National Bureau of Standards.

Commercial book publishers are eager to participate in the NSRDS program. Several manuscripts now in preparation will be submitted to competitive bidding by the publishing community.

It is still too early to make a reliable estimate of the financial return to be realized from the sale of documents, tapes, and other products and services. The estimate previously given, that it is expected to be a "significant, but not large" fraction of operating costs, still holds.

When the original hearings on the standard reference data bill were held before this subcommittee in 1966, Assistant Secretary of Commerce J. Herbert Hollomon testified that it was estimated that the eventual cost of the standard reference data program would be \$18 to \$20 million annually.

That figure has now been revised downward to approximately \$12 million.

Mr. DADDARIO. You revised that downward because of the return that you expect to get by the sale of some of these, or is this the overall cost not including such returns?

Dr. BRADY. This is the overall cost in addition to such return, figuring that the return would be of the order of \$2 million per year if we are operating at a \$12 million a year level.

Mr. DADDARIO. So does that bring you up to \$14 million or down to \$10 million? I don't know what process you are going through.

Dr. ASTIN. No; \$14 million.

Dr. BRADY. Roughly \$14 million, sir.

Mr. DADDARIO. I see.

Dr. BRADY. I would like to emphasize that this is a very rough estimate. The figure of \$12 million is based presently on the estimate of the international cooperation that can be obtained, as I will go into later.

In other words, the figure of \$18 to \$20 million annually to operate the program at a reasonable level to maintain currency with the literature is still our overall estimate; however \$12 million is now our estimate of the cost to us, with the rest of it borne by the cooperative groups in other countries.

Mr. DADDARIO. When we first held hearings on this subject, it is my recollection that it was estimated that of the total cost, 25 percent would be recoverable through the sale of the data. Is that a figure that still holds up?

Dr. BRADY. That is an optimistic estimate in my opinion, Mr. Daddario. We have made various estimates that have ranged from 10 to 25 percent, and the figure of 25 percent that was quoted at the hearings in 1966 was looking on the optimistic side.

Mr. DADDARIO. But there is a favorable expectation that goes with it. The overall cost has come down, as you see it.

Dr. BRADY. Yes, sir.

Mr. DADDARIO. Even though the return might not be as great, we are still somewhere in the same area of total funding, where that would be obtained.

Dr. BRADY. Absolutely, yes, sir.

The reason for this downward revision is the progress that has been made internationally in developing arrangements to share the effort of producing compilations of critically evaluated data.

The establishment of the U.S. program has stimulated interest among scientists and governmental organizations in other countries, resulting in numerous bilateral and multilateral discussions. Possible cooperation has been discussed with scientists from the United Kingdom, France, Germany, U.S.S.R., Japan, Canada, and Poland.

Multinational cooperation under the aegis of various international scientific unions has been underway for many years and is expanding under the stimulus of the current interest. The International Council of Scientific Unions has created a Committee on Data for Science and Technology (CODATA) whose function is to promote international cooperation, to serve as a channel of communication among projects in various countries all over the world, to encourage more scientists to undertake projects of this type, and to make recommendations

about needs and priorities to persons responsible for funding such projects in the various countries.

In July of 1968 CODATA sponsored a conference held near Frankfurt, Germany, which brought together approximately 100 scientists and government program officials from the major developed countries of the world—I think 14 countries were actually represented there—to discuss ongoing activities and the prospects for international cooperation.

Channels of communication established at that meeting are now being utilized in efforts to plan and coordinate projects undertaken jointly by American scientists and those of a number of other countries.

The Soviet Union has established a program patterned in many ways after that of the United States which they call the "State Service of Standard and Reference Data." Under the auspices of the U.S.-U.S.S.R. Cultural and Scientific Exchange Agreement, an exchange of visits is now being negotiated, hopefully to take place later this year. Our present evaluation of current work in the Soviet Union convinces us that the potential benefit of developing a significant exchange with the Soviet Union is substantial.

The standard reference data program is one of three areas in which NBS uses the special foreign currency program to promote its interests. A few projects are now active in India and in Israel; many worthwhile projects could be undertaken in Israel if funds were available. Present plans call for an exploratory mission to be sent to Yugoslavia and Poland to discuss projects that might be initiated in these countries.

The recent passage of the Standard Reference Data Act has focused the attention of technical program managers of the various government agencies upon our activities. Program managers from the Atomic Energy Commission, NASA, and the Department of Defense now look to NBS to provide data compilations in areas of general interest to them as well as to the entire technical community.

We welcome their interest and seek their advice on priorities. In the future, as our program develops, we hope to be able to satisfy a larger fraction of the needs of all segments of the technical community.

Mr. DADDARIO. When you work with the program managers of these other agencies on the value of data compilations, do you do this on a reimbursable basis?

Dr. BRADY. It is partly on a cost sharing basis. In other cases they may ask what data we have on a certain subject. If we have a project related to their needs we tell them in detail what is available.

We also consult with them on their evaluation of priorities in respect to new activities which we are considering.

Mr. DADDARIO. Is this a growing relationship? Because this would be one way to prove the way in which your data work is progressing. Is this a closer and closer contact all the time?

Dr. BRADY. It is a closer and closer personal contact between the program managers in our office and the program managers in the other agencies. The cost sharing arrangements seem to be more difficult to work out as the budget squeeze continues.

Mr. CABELL. Mr. Chairman.

Mr. DADDARIO. Yes, Mr. Cabell.

Mr. CABELL. May I ask, with reference to your international exchange and dialogs with the Iron Curtain countries, do you find

that there is really two-way traffic, where there is mutual benefit, or are they primarily on the receiving end and there is not a great deal of exchange involved?

Dr. BRADY. In our field, Mr. Cabell, it is a little too soon to be very specific.

Mr. CABELL. I see.

Dr. BRADY. We have examined some of the data compilations that the Russians have put out and they are good. They are comparable with the work that our people do. In the special field of thermodynamic data, there is a group at the Institute for High Temperatures in Moscow that has been conducting a project very similar to one that we have at NBS.

On a number of occasions people from our group have gotten together with people from the Soviet group. This exchange has been quite useful.

Mr. CABELL. One other question. I was interested in your statement that a great deal of work is potentially available with Israel. Now, would you clarify that?

Dr. BRADY. Yes, sir. The visits that have been made to the laboratories in Israel have shown quite a number of opportunities. An exploratory mission went to Israel, India, and Pakistan a little over 2 years ago to explore what projects might be of mutual interest.

We found in Israel that there were quite a number, and after the visit there we received the order of two dozen or more proposals that seemed to be of a great deal of interest to us.

We have been told that the excess currency status of Israel is in doubt and actually for the present fiscal year we have not initiated any new projects at all. We now have about four or five projects in Israel, but another dozen or so would be of considerable interest.

Mr. CABELL. In other words, that is research that they would like to have us do for them, rather than a matter of exchange of information.

Dr. BRADY. No. It is our using the foreign currencies to obtain data compilations and critical reviews carried on by scientists in Israel.

Mr. CABELL. I see. That clarifies it. Thank you.

Mr. DADDARIO. Dr. Brady, following that up just a bit, you mentioned the potential benefit of developing a significant exchange with the U.S.S.R. As I understand it, there is presently available to us publications of theirs in this area.

Ours are available to them.

Dr. BRADY. Yes, sir.

Mr. DADDARIO. Do you mean by the potential benefit here a cooperative working arrangement through which data will be accumulated leading to publication?

Dr. BRADY. Yes, sir. We envision perhaps an agreement under which the scientists in the Soviet Union would work on a particular group of compounds for a particular group of properties while the group in the United States would select different properties or different compounds and not cover necessarily the same work.

In other cases, there would be overlap and the results would be compared so that additional confidence would be obtained by having available the evaluations of the two competent groups.

In the specific case that I mentioned, the thermodynamics area, we are attempting to develop an internationally agreed-upon set of key data that would be generally adopted by people as the basis for further development of the whole set of thermodynamic tables.

There are approximately 150 to 200 key values which once set play a great influence on determining thousands and thousands of other figures that would be derived from these.

Under the auspices of CODATA, a task group on key thermodynamic values has been established, consisting mainly of U.S. and U.S.S.R. people, which is attempting to develop this set of values.

Mr. DADDARIO. Fine.

Dr. BRADY. The authorization bill, H.R. 4284, that has been introduced at the request of the administration would authorize the appropriation of a total of \$6 million for the 2 fiscal years 1970 and 1971.

The budgeted figure for fiscal year 1970 is \$2.4 million. This may be compared with our present authorized figure of \$1.86 million. The balance of the authorized amount would be available for fiscal year 1971 plus coverage of any salary increases that may be approved. The figure of \$6 million includes up to \$300,000 for the special foreign currency program, of which \$150,000 is proposed for fiscal year 1970.

Let me itemize a few of the needs that we would attempt to satisfy with the resources that would be authorized under H.R. 4284. I have already mentioned the work of the Atomic Collision Cross Section Center at the NBS Boulder Laboratory. This group has been so successful in the analysis of experimental uncertainties that we want to expand their program. The payoff will come in increased usefulness of experimental measurements costing millions of dollars.

To date, our program to analyze the data of chemical reactions has emphasized reactions in gases. However, many important research and practical problems are concerned with reactions in solutions. For example, the procedures for control of stream and river pollution must be based on a detailed knowledge of the rates and mechanisms of reactions of possible pollutants with water.

We propose to establish a Center for Solution Kinetics Data to focus on these and related problems.

Other needs exist for evaluated data on the pressure-volume-temperature relationships of gases. These properties are important in combustion, in refrigeration, in materials development, and in studies of the atmosphere. We propose to undertake new projects in these areas.

But these are only a few specific instances. In more general terms, it is planned to increase the level of effort most substantially in the fields of atomic and molecular properties and in thermodynamic properties.

A major effort is planned for the first time on nuclear properties, and additional attention is to be focused on special services to make our results more conveniently accessible to all.

The increased authorization contained in H.R. 4284 is consistent with orderly progress toward the goals of the National Standard Reference Data System, taking into account the overall objective of achieving balanced and orderly progress toward the total goals of the National Bureau of Standards and the Department of Commerce.

We are confident that with the program that would be authorized by the bill before this subcommittee, we can materially advance the policy

of Congress expressed in Public Law 90-396 "to make critically evaluated reference data readily available to scientists, engineers, and the general public."

Thank you, Mr. Chairman.

Mr. DADDARIO. Why are you specifically setting aside the fields of atomic and molecular properties and thermodynamic properties as areas where you wish to increase your level of effort?

Dr. BRADY. These areas have been identified by a variety of ways as the ones that are of highest priority for additional effort.

We have a number of advisory panels organized and operated for us by the National Academy of Sciences, and National Academy of Engineering, on which we rely quite a great deal for advice on priorities of activities and on identification of specific areas in which additional effort is necessary.

That is one of the mechanisms that we have used. Another mechanism that was used was the survey that I mentioned of the members of the American Chemical Society in which they were asked which kinds of properties they were most in need of in their everyday work. The kinds of properties that were specified fall largely into the two groups of atomic and molecular properties and thermodynamic properties.

A further evaluation is derived from our own analysis of science and technology in the United States and our personal judgment as to which fields are most deserving of increased attention.

Mr. DADDARIO. When we had the debate on this subject on the floor, one of the members of this committee, in reply to the monetary return being somewhere between the 20 to the 200 to 1 ratio, questioned that if this was so and if it was of such benefit to industry, why didn't they pay the full amount?

Dr. BRADY. The benefits as we see them are to the entire economy. They are shared by industry, by academic institutions, and by the Government. Any specific activity that would be undertaken by a particular industrial firm would be concentrated on a small group of properties or substances that were of primary interest to its own company.

And indeed every industrial firm of any magnitude does have its own private proprietary data book, in which are listed the properties of the substances that they are particularly interested in.

But it has turned out to be not effective, except in a very small number of instances, to get industry to work cooperatively, to fund jointly any systematic activity, either through a combination of industries or trade associations.

There are a few cases of successful cooperation. The American Petroleum Institute does sponsor work of this kind at the Texas A. & M. University and a couple of other places. But in general the level of effort that industry will support is limited. Each company is interested in supporting only those items of interest to itself.

Furthermore, they would not be particularly interested in publishing these results and making them available for other people to use. Perhaps Dr. Cross might like to comment on this point.

Dr. CROSS. I think you have covered it very well. I agree with you that it is very difficult to get an industrial association to put up sizable funds into any program.

Mr. DADDARIO. Dr. Astin.

Dr. ASTIN. May I?

Mr. DADDARIO. Certainly.

Dr. ASTIN. About the only way we could recover costs—that is to establish a procedure to have industry pay—would be through the sale of publications or services. But if one puts a high enough price on the publications to recover all costs, then the same price must be paid by researchers in universities.

I recall when Dr. Seitz, the president of the National Academy of Sciences, gave testimony with respect to the standard reference data bill, he made a special plea that any selling costs we put on the publications not be so high that they would tend to put the publications out of the reach of the university scientists.

This is one reason why we are a little pessimistic now that we will get back as much as 25 percent through our ability to recover costs through sales.

A related problem in this area is that if we set a price for a publication too high, it would tend to lead perhaps to pirating of the publication; that is, people would buy one copy if it were very expensive and infringe copyrights by making duplicates for internal use. On the other hand, if the publication is priced reasonably then we will probably sell more of them.

So we have to strike a balance here in the price of the publication versus the number we expect to sell.

Mr. DADDARIO. When you sell your services, Dr. Astin, if a company were to come to you and ask you to evaluate certain critical data for them, under those circumstances they would pay for the whole thing.

Dr. ASTIN. Oh, in a situation like this, yes, we would expect them to pay the full cost because it would be a special service limited to them.

Mr. DADDARIO. Would that information be available only to them or would it be fed into the overall critical data system?

Dr. ASTIN. It would be fed into the system. Even if we undertook a special job for one company, we would make the results of this investigation available to everyone.

Mr. DADDARIO. Part of the determination of what price you will charge will evolve, I would expect, in time to come through this competitive bidding process which you are about ready to undertake?

Dr. ASTIN. That is correct.

Mr. DADDARIO. So the judgment of people who have done work in this area will necessarily relate itself to what the competitive situation might be or will be?

Dr. ASTIN. That is correct.

Mr. DADDARIO. Mr. Cabell.

Mr. CABELL. I assume you are recovering at least your composition and printing costs on these?

Dr. BRADY. We are not at the present, because almost everything goes through the Government Printing Office, and the Government Printing Office, you know, charges the agencies for composition and printing.

Mr. CABELL. You mean that our Government Printing Office is a higher priced printing agency than maybe a private print shop?

Dr. BRADY. No, not that, but when we send a publication to the GPO we have to pay for composition.

Mr. CABELL. Yes, but the cost of composition, which is part of the cost of printing, you do not recover that?

Dr. BRADY. No, sir.

Mr. CABELL. I see.

Mr. DADDARIO. Mr. Brown.

Mr. BROWN. I do not have any very disturbing questions about this testimony, but I would like to clarify a couple of points.

You have stressed several places in your presentation the physical and chemical data. Are you leaving out the fields of data which are related to radiation and other properties which aren't classified strictly as material and chemical?

Dr. BRADY. We include radiation within the physical properties. But the scope of the program is well-defined properties of well-defined substances. Thus if the composition is too complicated or too variable, so that the property that you are measuring depends on poorly controlled factors, we consider that to be outside the scope of this system at the present time.

Mr. BROWN. But you do not involve yourself with, say astronomical measurements, the characteristics of cosmic rays, or things of that sort?

Dr. BRADY. The characteristics of fundamental particles, cosmic rays, and so forth are considered to be part of the program; yes, sir. Fundamental particles, nuclear properties, properties of single atoms, molecules, other well-defined systems, these are all within the scope of the program. Where we begin to be uncertain about the appropriateness is on physical data involving the properties of very large systems, such as the earth or solar system or oceans. This kind of information is not sufficiently well defined to be within the scope of the program.

As a practical matter, it has not caused us any problems, because we have considered that it would be important for us to focus on a relatively small area and get that as well in hand as possible before broadening out to some of these other kinds of data.

Mr. BROWN. Perhaps the distinction is unimportant, but we normally think in terms of matter and energy, and you seem to be saying that you are just measuring the properties of matter but not of energy.

Dr. BRADY. I did not intend to convey that, no, sir. We are considering matter and the interactions of various forms of energy with it. That is considered to be within the program. The interaction of radiation of all kinds with matter is within the scope of the program. So we are considering the properties of individual substances and the interactions of those substances with energy in all its various aspects. That is within the program, yes, sir.

Mr. BROWN. I suppose in a technical sense there isn't any such thing as energy that doesn't interact with matter in some way or another.

Dr. ASTIN. Yes.

Dr. BRADY. Yes, sir.

Mr. BROWN. With regard to your data analysis centers, I presume each of the centers has a functional responsibility for a certain area of data—

Dr. BRADY. Yes.

Mr. BROWN. And that they are mixed as to their funding and managements. Some are directly and fully funded and controlled by

the Bureau and others are not. Can you explain that just a little bit more clearly?

Dr. BRADY. Let me explain by an illustration. The Thermo-Physical Properties Research Center at Purdue University is a rather large operation involving funding of about three quarters of a million dollars per year. Most of this funding is provided by the Air Force and additional amounts by other agencies of the Department of Defense. We participate in the funding of this center, providing a little more than 10 percent of their total funding. But our funding is for a specific evaluation job. Most of the Air Force funding that goes into it supports the literature survey that the center does, the preparation of the abstracts, the storage function, retrieval function and so on, and also the compilation of nonevaluated data. This center recently put out a nine volume set of books, about so big (indicating with hands) containing data that were extracted from the literature that they had reviewed. This work was sponsored by the Air Force.

Now, our work resulted in a much smaller volume, about so big (indicating with fingers) but whose contents were critically evaluated. We emphasized that the evaluation is an essential feature of our task.

Mr. BROWN. So the data centers would include those which are 100 percent funded by the Bureau and, to the other extreme those which are, say, 10 percent funded by the Bureau and partially funded by another governmental agency or by the university.

Dr. BRADY. Yes, sir.

Mr. BROWN. Do you have any involvement with private industry or nonprofit associations?

Dr. BRADY. No, sir; except for the Thermodynamics Data Center at Texas A. & M., which we fund jointly with the American Petroleum Institute.

Mr. BROWN. Let me ask just one additional question. You have painted this bleak picture of the proliferation of scientific data and your inability to keep up with it, critically analyzed data at least. This rapid growth applies to the whole field of scientific information. Do you have any way of evaluating the nature of the curve we are on? Is it one that keeps going up at the increasing rate or does it level off at some point?

Dr. BRADY. It can't possibly keep on going up.

Mr. BROWN. Do you have any theoretical analysis as to what is going to happen to it?

Dr. BRADY. Well, my projection certainly indicates it is going to start curving over very soon. And I think that in the United States, the curve has already started to bend over. But as I pointed out in the statement, the total world output still seems to be increasing in this steep curve, but even taking into account all of the output produced anywhere in the world, I think it is going to curve over very soon indeed within the next 5 to 10 years, perhaps.

Mr. BROWN. With regard to the critical data, does there come a point at which you develop a theoretical system, which is adequate to comprehend all the data and which makes it less necessary to have the specific data, as long as you have the theoretical explanation? In other words, for example, just take something very simple like the coefficient of expansion of a metal. The coefficient may tend to vary with temperature, and you may need measurements at different

temperatures over a very wide range. But if you have a theoretical explanation of how it varies over the same wide range, you don't need to compile all this data.

Dr. BRADY. That is right.

Dr. ASTIN. Some of the NSRDS programs involve theoretical compilations.

Dr. BRADY. Yes. This depends on the field, of course.

There are many areas where a theoretical or semiempirical relationship is sufficiently well known, so that you can calculate the value at least as well as you can measure it. This is true for some kinds of thermodynamic properties. For example, if you know enough of the properties of a group of hydrocarbons, then you can compute some of the properties of the higher members of the series, at least as accurately as you can measure them. And in some of the work that we are supporting, we expect that the result, instead of being a great long table of measurements, will be a curve, or an equation, which could be put into a computer.

Mr. BROWN. I would expect this would be true of such things as your nuclear cross section measurements at some point in time with regard to the whole spectrum of terms.

Dr. BRADY. Probably at some point in time, but that is one field in which the theory still is not sufficiently well known, so you can make accurate predictions.

Mr. BROWN. That is what I mean. The theory is not well known.

Dr. BRADY. Yes, sir.

Mr. BROWN. But some day when we have a unified field theory that encompasses all of these things, it would be very simple with your slide rule to figure these things out.

Dr. BRADY. Or with your computer.

Mr. BROWN. I mention this only as some way to envision a little hope for not being inundated with constantly increasing masses of data. The antidote would seem to be a better understanding of what their characteristics are based upon. This ultimately will involve a knowledge of nuclear structure, and many things which are included in it.

Dr. BRADY. A great deal of work at the National Bureau of Standards is concerned with understanding those relationships between structure and composition and the measurements that are made.

Mr. BROWN. That is all.

Mr. DADDARIO. Mr. Cabell?

Mr. CABELL. No further questions.

Mr. DADDARIO. I think we have done pretty well here this morning, Dr. Astin, in getting this information before the committee.

Do you or Dr. Cross have something further to add.

Dr. ASTIN. I would like to ask Dr. Cross if he would make some general comments about the program as he sees it.

Dr. CROSS. Yes. I mentioned I am here strictly as a member of the visiting committee. I have no direct connection with this program, nor does my university.

I have had contacts since the inception of this program and I have attended at least three meetings of outsiders called in to advise. First, I want to say they are a tough crowd. They are very, very critical and spend literally days thinking this over and helping assign priorities, helping to find people to do the work. And as I mentioned before, it is a very capable group.

In history, there was the famous International Critical Tables, which was really put together at the instigation of the Bureau of Standards, I believe. Dr. Edward W. Washburn was the spirit of that effort. It was completed in the late 1920's. About 12 years ago I was on a panel of the Chemistry Division of the National Science Foundation, and we spent most of an afternoon discussing this problem. The magnitude was so overwhelming that we decided the Science Foundation could not undertake it and that there would never be again an issue called the Critical Tables as one set of books, because the job had grown about 100-fold since that was done. The tactics thought up at that time were just exactly what is being applied here, namely that you subdivide science into fields and bring different fields up to date at different times, with no attempt to do them all at once.

The importance of the program has been covered adequately. I have a story which a friend, Prof. Henry Eyring, told about 5 years ago, at one of our visiting committees. He suggested that the thermodynamic tables put out by the Bureau of Standards (NBS Circular 500, published in 1952) had probably saved our economy more money than the entire cost of the Bureau since its inception. I have no documentation on that, but I think it is a good illustration, and one could say many times the entire cost and still have a basis for backing it up.

In reference to the comments of Mr. Brown concerning the use of theory, it is worthwhile to point out that even in the old Critical Tables much of the data were presented in the form of coefficients of equations based upon theoretical concepts. So even in those days they made use of theory wherever it was applicable.

I think I have run out of spontaneous remarks. I would be glad to attempt to handle any questions of how this looks to someone a little bit on the outside.

Mr. DADDARIO. Well, you have asked the question. Why don't you answer it? How does it look to you on the outside?

Dr. CROSS. Well, my interest personally in being here is my own conviction that this is a very, very important program, that it has been hanging over the heads of the scientists ever since World War II, and this is the first real concerted effort to meet that problem.

Mr. DADDARIO. Dr. Cross, recognizing the problems that we have in this area and that the National Bureau of Standards is a remarkable good place to get the work done, do you think the private publisher with a competence in this area will have an opportunity to participate? Do you see this as a workable possibility?

Dr. CROSS. I will speculate in this way. The private publishers do a promotional job that Government really can't do. I was consulted by a publisher on what I thought of his prospects. My answer, I threw it back to him, was that he would have to gamble on whether his circulation would supplement the Bureau's own circulation through Government documents. I think some people would feel that maybe they would multiply the total circulation by as much as a factor of three.

Now, I can't really say why I would think that way, but you know as the program gets well known it could be that requests for the bulletins issued by the Government would saturate the market.

Mr. DADDARIO. You mean marketing capabilities and other promotional approaches?

Dr. CROSS. Yes.

Mr. DADDARIO. Do you find, Dr. Astin, that as you set up the possibility of competitive bidding with publishers, that there is an interest?

Dr. ASTIN. A real interest in the private publishing area; yes, sir.

Mr. DADDARIO. That was something that you had planned and had expected in the first instance, as I recall?

Dr. ASTIN. Yes, sir; we anticipated that there would be and we have not been disappointed in this.

Mr. DADDARIO. Are there any further questions?

Mr. CABELL. I have no more.

Mr. BROWN. No.

Mr. DADDARIO. We will most likely have other questions for the record, Dr. Astin. We will get those to you as quickly as possible.

Dr. ASTIN. Very good, sir.

Mr. DADDARIO. We appreciate your coming, and we appreciate Dr. Cross' presence. We do agree that this is a very important piece of business, and I am sure you have the support of the subcommittee.

Dr. ASTIN. Thank you very much, Mr. Chairman.

QUESTIONS SUBMITTED TO DR. E. L. BRADY BY THE SUBCOMMITTEE ON SCIENCE, RESEARCH, AND DEVELOPMENT

1. How large is the total standard reference data effort in the United States, including both private and government? How large is the worldwide effort?

The total expenditure on standard reference data in the United States is estimated to be about \$4 million per year (\$1.86 million through NSRDS and most of the remainder by other government agencies). The worldwide effort is difficult to express in dollar terms. However, on a man-year basis, the effort in the rest of the world is estimated to be about one-half of the U.S. effort. The relative contribution of the non-U.S. groups is increasing rapidly.

2. In the Standard Data Act, we gave the Secretary of Commerce authority to copyright standard reference data. Has this authority been used? What were the circumstances? If not, do you expect it to be used in the future?

The authority to copyright data, granted by the Act of July 11, 1968, has not yet been used. This authority is necessary to facilitate publication of data compilations through commercial channels. Discussions have been conducted with private publishers and procedures are now being developed to assure their participation in the program. When these arrangements are completed, hopefully within the next few months, copyright will be obtained by the Secretary of Commerce on all new compilations of possible interest to commercial publishers, so that private firms can be licensed under contract to publish and disseminate the data.

3. What percentage of the standard reference data costs to date have been recovered through the sale of the data? What do you expect in the future?

No costs have yet been recovered. A computer tape of a tax-editing program has recently been placed on sale through the Clearinghouse for Federal Scientific and Technical Information. Approximately \$45.00 per sale will be returned to NSRDS, and we estimate an ultimate sale of a few hundred tapes.

Recovery of partial costs on regular printed data should begin upon the completion of arrangements for dissemination of the data through private publishers.

During the original hearings on the Standard Reference Data Act, some estimates were made of cost recovery up to 25%. We now feel that this estimate was too optimistic, and that a recovery of 10 to 15% of costs is a more realistic goal.

4. Does this bill have the approval of the Nixon Administration? Has the amount been changed? Has the budget for the overall Bureau of Standards been changed?

This bill has been approved by the Nixon Administration (see letter of April 17, 1969, from James T. Lynn, General Counsel of the Department of Commerce, to Chairman Miller).

No change has been made in the requested authorization for FY 1970-71. However, the FY 1970 budget as originally submitted to Congress in January 1969 requested an appropriation of \$2.49 million for the Office of Standard Reference Data. This was subsequently reduced by \$100,000 to \$2.39 million in the amended budget. However, no change was made in the requested authorization in order to allow for 1970 pay raise supplemental funding.

As for the Bureau in total, the recent amendment reduced the budget for Research and Technical Services by \$1.4 million to a new total of \$38.7 million and Plant and Facilities by \$1 million to a new total of zero. In the case of Plants and Facilities unobligated balances from prior appropriations will be used to accomplish the program at the budgeted level of \$1 million.

APRIL 17, 1969.

HON. GEORGE P. MILLER,
*Chairman, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.*

DEAR MR. CHAIRMAN: On January 17, 1969 then Secretary of Commerce Smith submitted to the Congress a draft of legislation "to authorize appropriations to carry out the Standard Reference Data Act."

This legislation was introduced by you as H.R. 4284. The Department of Commerce has reexamined this legislation and continues to urge its enactment.

We have been advised by the Bureau of the Budget that there would be no objection to our continued support of this legislation.

Sincerely,

JAMES T. LYNN,
General Counsel.

5. *How many employees are now involved in the Bureau's standard data program? How many are proposed for FY 1970 and 71?*

A total of 50 employees are currently involved in standard reference data activities within NBS. Of these, 36 are employed in the various NBS data centers, while 14 are in the OSRD office. The office staff breaks down to 6 involved primarily in management, 3 in the information services component, and 5 involved in research on data systems and information retrieval.

The requested budget for FY 1970 includes an increase of 4 NBS technical positions. The request for FY 1971 includes 12 new positions.

We estimate that about 100 people are involved in the data centers operated under contract. Most of these are part-time workers; the total contract program amounts to about 30 man-years.

6. *Please provide more detail on how the funds will be spent in FY 1970 and 71?*

The breakdown of the projected spending by program element is given in the charts. Over the two year period the largest percentage increase is in the field of nuclear data. The NSRDS contribution in this area has been very small to date; however, because of the need to increase the effort in various nuclear data centers now supported by the AEC, we expect to enter joint funding arrangements with the AEC in order to expand these centers. Fairly large percentage increases are also projected in chemical kinetics and thermodynamics and transport properties. The greatest increase in absolute terms is in the latter field, which forms the largest of the NSRDS programs. A part of this will go into funding various U.S. groups which are participating in an international effort to provide critical tables for all industrially important gases.

A portion of the requested increase will be used to expand certain existing data centers which are not able to cope with the rapidly increasing literature in their area. The remainder will be used to start new data centers. A list of the proposed new centers is attached, and an estimate of the initial annual cost is included. Most of the new centers will be contract operations.

OFFICE OF STANDARD REFERENCE DATA—PROGRAM EXPANSION

[In thousands of dollars]

	Total, fiscal year 1969	Expansion, fiscal year 1970	Total, fiscal year 1970	Expansion, fiscal year 1971	Total, fiscal year 1971
Nuclear.....	57	20	77	170	247
Atomic and molecular.....	433	103	536	180	716
Solid state.....	195	20	215	137	352
Thermodynamic and transport.....	565	85	650	377	1,027
Chemical kinetics.....	146	40	186	114	300
Colloid and surface.....	65	20	85	62	147
Data systems design.....	119	46	165	36	201
Information services.....	59	36	95	79	174
Management office.....	231	10	241	5	246
Subtotal, RTS.....	(1,860)	(380)	(2,250)	(1,160)	(3,410)
Public Law 480 funds.....	0	150	150	0	150
Working capital fund.....	0	0	0	50	50
Total.....	1,860	530	2,400	1,210	3,610

NEW DATA CENTERS PLANNED FOR FISCAL YEAR 1970 AND FISCAL YEAR 1971

	NBS	Amount	Contract	Amount
Nuclear.....	Gamma ray analysis.....	(\$13K)	Gamma ray spectroscopy.....	(20)
			Nuclear data group ¹	(65)
			Table of isotopes ¹	(10)
			Bubble chamber data ¹	(10)
Atomic and molecular.....			Plasma properties.....	(10)
			Raman spectra.....	(14)
			ESR spectra.....	(5)
Solid state.....	Mossbauer effect.....	(5)	Superconductivity.....	(10)
	Electrical properties of cryogenic materials.....	(10)	Elastic constants.....	(20)
Thermodynamics and transport...	PVT of gases.....	(15)	Rare earths.....	(20)
			High temperature thermo. properties.....	(30)
			PVT of gases.....	(50)
			Thermo. properties of organic compounds.....	(30)
Kinetics.....			Solution kinetics.....	(40)
Colloid.....	Solid surfaces.....	(24)	Physical adsorption.....	(30)
			Interfacial tensions.....	(10)
Total for new data centers (Annual cost).....		\$67K		\$374K

¹ To be jointly funded with AEC.

7. Two years ago the Bureau estimated that 50% of the standard data work was done in-house, and that as the program matures about 75% of the work would be contracted out. How has this worked out so far, and how do you see it for the future?

In FY 1969, approximately 59% of the spending on data center operations was within NBS. Our projections for the next two years would reduce this ratio to 54% in FY 1970 and 48% in FY 1971. The suggested figure of about 25% in-house work as an ultimate level still appears reasonable. This might be attained in about five years if the total program expands at the rate which we feel necessary.

8. Please provide a copy of the cost benefit study which indicated savings would be between \$20 and \$200 for each dollar invested in standard reference data.

A copy of the study, which was carried out in 1967, follows:

ECONOMIC VALUE OF THE NATIONAL STANDARD REFERENCE DATA SYSTEM

The product which the National Standard Reference Data System provides is valuable to the technical community because numerical answers are more readily accessible, and more reliable. Dollar benefits accrue through:

(1) Saving of time of users in searching through scientific reports for numerical data.

(2) Saving of time in evaluating and selecting most reliable answers from among those found in scientific reports.

(3) Saving of time and materials spent in unnecessary measuring of properties of substances for which the data actually reported in the literature could not readily be found.

(4) Saving of time, equipment and materials through use of better (more reliable) data.

Some of these savings—those in the first two categories—can be estimated quantitatively: specific calculations are shown below.

In other cases, only subjective and qualitative estimates can be made, partly because there are barriers to obtaining the relevant figures. (These barriers include personal and psychological barriers to admitting mistakes, professional ethics, and industrial security considerations.) Moreover, in some ways the saving in the latter two categories is inherently not subject to quantitative economic analysis, and a descriptive study is the best that can be done. Such descriptions are also given below.

Finally, other evidence is discussed, in the form of personal comment or reaction, which indicates that the NSRDS has a program with positive economic value to the nation.

A. QUANTIFIABLE SAVINGS

Several data compilation projects have been in existence for years, and their products have been widely used in the technical community. At least some information is available on the sale and use of the compilations, and on the cost of producing them. These figures, and some very conservative approximations derived from the known work habits of scientists and engineers, permit calculations of the dollar savings involved.

1. NBS Circular 500, "Selected Values of Chemical Thermodynamics Properties" was issued in 1952. (A revision is now being published under sponsorship of the NSRDS.) It contained over 8,000 data-point entries for numerical values of certain fundamental thermodynamic properties of all the elements, some inorganic compounds, and all organic compounds containing one or two carbon atoms. Over 7,000 copies of this book were sold, mostly to academic technical laboratories, industrial laboratories, and government research laboratories. Each copy would, under these circumstances, be referred to by at least five research workers, development engineers, faculty members or graduate students. (Five is a very conservative number—it might be as high as twenty people.)

Assume, then, that 35,000 people have used this book in the past twelve years. Assume further that each one is interested in only a very small fraction—1% of the contents, and has used it only when numerical answers of the highest reliability were needed. Assume each user has looked up thirty answers in the twelve year period.

Each highly reliable answer could be obtained from Circular 500 in a few minutes; lacking that compilation, a careful literature search would have been needed to locate three or four experimental numbers and correlate them. Four hours of a scientist's time would be a minimum for such searching. At \$12 (1967 figures) per hour, (including overhead), each such answer obtained would have cost \$50.

Each user therefore, was saved

$$30 \times \$50 = \$1,500 \text{ in 12 years}$$

$$35,000 \text{ users} \times \$1,500 = \$52 \text{ M}$$

Thus the savings effected through the availability of Circular 500 have been at least \$50 M. The work of preparing the volume would have cost \$1 M at present salary levels. The ratio of benefit to cost is 50 to 1.

From another direction, one may estimate the cost of the original research work which was condensed and compressed into Circular 500. Approximately 10,000 scientific journal articles were referred to in its preparation and 5,000 of these were actually studied critically. By current figures, the typical journal article represents a research investment (scientist's time, equipment, samples, etc.) of \$30,000. The total research investment was therefore \$300,000,000. The added effort which increased the availability of this work cost only 0.3% of the total.

2. The JANAF Thermochemical Tables, prepared under DoD contract by scientists at the Dow Chemical Company, provide data on some 500 compounds of great importance to certain defense projects and to scientists active in studies of high energy fuel systems. Most of the people who receive the tables use them frequently. Assume that the 1,000 subscribers who receive the tables make five references to them each week. This leads to a total of 250,000 users of the tables each year, over 50% of whom are working on federal government R&D programs.

If each use saves only \$20 in search time (less than two hours per use—a very conservative estimate), the annual saving is \$5 M. The tables cost \$250 K per year to issue and keep up-to-date. The ratio of annual benefits to annual cost is 20 to 1.

3. Similar figures can be applied to the tables of thermodynamic and physical properties of hydrocarbons and related chemicals issued under API Research Project 44, supported by the American Petroleum Institute, and to the parallel data compiled under the Manufacturing Chemicals Association Research Project on other organic chemicals. The two sets of loose-leaf tables updated systematically give data on some 3,000 compounds. The compilation project costs about \$250 K per year. There are about 1,500 subscribers, and it is estimated that each copy of the data sheets is used at least five times per week (in many instances, when a single oil company is at the critical stages of refinery engineering design, this figure may go up to 50 or 100 uses per week). At \$20 per use, 250 uses per year per copy, $\$20 \times 250 \times 1500 = \7.55 M/year, for a benefit to cost ratio of about 30 to 1.

The three examples above concern reduction in searching time, and are all analyzed in the same manner. To estimate the savings due to reduced duplication of effort, a different analysis is appropriate.

SAVINGS ACHIEVED THROUGH SPECIFIC DATA COMPILATION PROJECTS

Project	Number of users	Cost of production	Established savings	Benefit cost
NBS C. 500.....	35,000	\$1 M.....	\$50 M.....	50/1
JANAF tables.....	1,000	\$250 K/yr.....	\$5 M/yr.....	20/1
API, MCA tables.....	1,500	\$250 K/yr.....	\$7+M/yr.....	30/1

4. The Nuclear Data Project established in 1945 and financed by the U.S. Atomic Energy Commission publishes Nuclear Data Sheets, giving numerical data in tabular form and decay schemes in pictorial form. The compilers cover the relevant scientific literature comprehensively, and the data sheets are accepted by workers in the field as the immediate reference source as well as the basic authority. There are about 1,000 subscriptions, representing a total user population of 3,000 nuclear scientists who are concerned with data of the type covered. The cost of reviewing each paper in the literature is (on the average) \$125. It would cost the typical skilled scientist twice as much, since he is not set up to do the job efficiently.

Naturally, not every scientist would need to duplicate 100% of the effort. A conservative estimate of each scientist's field of interest is 1% to 5% of the total information. Assuming that each one of the 3,000 users of the Nuclear Data Sheets did his own reviewing of 1% of the total, there would be a $(3000 \times 1\% =)$ 30 fold duplication.

Including the 2 to 1 increased cost for the individual worker, the benefit to cost ratio is 60 to 1. At least 70% of the R&D effort which involves nuclear data is sponsored by the federal government.

B. QUALITATIVE ECONOMIES

The economic benefits of *more reliable* data cannot be computed in the same way as the benefits of *more accessible* data. The benefits are real, none the less, and depend on two facts—first, not every numerical answer reported in the scientific literature is as correct as the author claims; and second, the scientists and engineers who use numerical data are aware that errors do exist.

The NSRDS seeks to improve the reliability of numerical answers available to the technical community. The work will be done by a large number of scientific specialists, each giving close attention to the area of his own greatest competence. Thus *all* users will have the advantage of compilations prepared by experts. Specific benefits will be obtained from reduced number of mistakes, and fewer faulty decisions, such as the following situations:

1. Many research and development projects, early in their history, come to a critical decision point—can the product be made with existing plant heating or cooling equipment; can it be made to sell for less than \$X per pound; will the new chemical solution be stable when stored in glass bottles; will the desired chemical reaction supply the new product in high yield; etc. Yes or no answers to questions like these result in decisions to continue or abandon many projects. But the

answers themselves may depend on numerical data on heat capacities, thermodynamic activity coefficients, photolysis rate constants, equilibrium constants. If the numbers used in calculating the answers are incorrect, some invalid "no" answers will be obtained, and potentially valuable projects will be abandoned which could have succeeded.

2. Much more costly (in an immediate sense) are research projects which received the green light based on faulty data. When a decision point is passed, the project is usually scaled up. More man-hours are scheduled, larger-scale equipment is purchased. If the decision to go ahead was invalid, the cost may run to hundreds of thousands of dollars especially in the pilot plant stage.

3. Because so many numerical answers are of uncertain reliability, most industries adopt a procedure of gradual scale-up, going through the cycle of bench-scale, large laboratory scale, pilot plant and semi-works development. These successive expansions help to answer many questions and probably could not be eliminated in many cases. But with adequate resources of reliable numerical data pilot plant and semi-works operations could be designed much more efficiently and the costs reduced by a factor or two or even ten in many cases. Only the key points of uncertainty would require testing, and the reliability of the pilot-plant results themselves could be greatly increased.

4. A familiar expense in all development and design projects is overdesign. Overdesign has two aspects, one of which appears to be inevitable. Generous allowances for personal safety, expanded use, greater versatility, and so on, are evidence of good engineering and foresight. But overdesign and over-construction required by unreliable input data represent unnecessary and avoidable expense. Any program, such as that being organized by the Office of Standard Reference Data, which provides greater reliability of data on the properties of materials, can bring about substantial economies. Such potential savings are greatest in the areas where weight and size are critical factors (e.g., aircraft and aircraft components; space science and technology; miniature instrumentation; computer technology, biological and medical analysis, diagnosis and monitoring) because in many cases the need to overdesign makes the proposed design unacceptable because of fuel demands, size, weight or flexibility.

The economic benefits discussed above are, to a certain extent, subjective or intangible in nature. It is next to impossible to estimate the value of something that might have been done but wasn't. Moreover, scientists, like other human beings, are reluctant to publicize their own mistakes and those of their associates. Dollar figures are, therefore, hard to obtain.

Perhaps the best estimate is based on the overall picture. The total R&D budget of the country (including the federal government) is over \$20 billion per year. A 1% increase in efficiency in spending this money would generate \$200 M in annual savings. We believe that a 1% increase in efficiency is a minimum figure to be expected from full-scale operation of the NSRDS. Present compilation efforts cover less than 20% of the needed data, so that there is ample opportunity for real economies.

C. PERSONAL REACTIONS SHOWING THE VALUE OF THE NSRDS

One measure of the value of the NSRDS is the reaction of scientists who are potential or actual users of the System. Listed below are some of the public or private ways in which scientists have indicated their need for reliable numerical answers.

1. The Office of Standard Reference Data has so far concentrated its data compilation programs in six technical areas. In each of these six, an Advisory Panel has been assembled comprising leading scientists who have been willing to donate their time to make sure that the program was well planned. The advisors are busy men, and their participation for two to four days per year is a definite endorsement. (In the seventh area, Mechanical Properties, an NBS staff panel has been assembled. Outside advice will be sought later.)

2. Brief public announcement has been made on several occasions that a certain organization was setting up a cooperative effort with the Office of Standard Reference Data. (All three announcements were made by the organization, not the Office of Standard Reference Data.) In each case, there has been a prompt influx of inquiries to the Office of Standard Reference Data, asking when tables of data or loose-leaf data sheets would be available. In one case, more than 50 requests for specific data have been received.

3. A questionnaire survey was conducted by the American Chemical Society (for the Office of Standard Reference Data) of 100,000 chemists and chemical

engineers, to determine needs for an interest in data compilations. Replies identify more than two hundred individuals, isolated and often unpublicized compilation projects being conducted by scientists on their own responsibility, or as part of a company program. This is in addition to the conventional "data book" which most chemical companies maintain on a routine basis. The Office of Standard Reference Data feels that there is a need for some sort of coordination of such work, and that the large number of people already involved is a clear indication of its importance.

4. The International Critical Tables, prepared under administrative direction of the National Academy of Sciences in the period 1926-1934, is the only comprehensive compilation of critically evaluated numerical data of the physical sciences. It is badly out-of-date. It covers less than 1% of the intended scope of the NSRDS, partially because of the expansion of established fields of science, but principally because whole new fields of scientific knowledge have been born in the intervening thirty years.

And yet, no present day technical library could be without a set of the ICT. It is still a major reference book. It still sells a substantial number of copies each year in the U.S. and abroad. It is still in demand because there is no critical reference work more up-to-date to take its place.

The continuing use of the ICT is a clear endorsement of the goals of the NSRDS—to provide reference data of the same high quality, in up-to-date form.

9. *If savings up to \$200 can be expected, why shouldn't the users pay the full cost for the publications, leaving a net cost savings of \$199?*

There are many problems in attempting to charge the user for the full cost of producing a compilation of standard reference data. Any estimate of the benefit-cost ratio is only an average figure, so that it cannot be expected to apply to every user nor to every compilation. Most users are unable to predict in advance the benefit they will personally receive by spending a given sum to purchase a compilation. If the price is very high, a potential user may well decide that his benefits are too uncertain to justify the expenditure.

Furthermore, these estimates of benefit-cost ratio are based on past experience. When a new compilation appears, the full benefits may not be clear. Again, if the selling price is based on full cost recovery, it may initially discourage many potential users who will decide that their benefits are marginal. A good example is the compilation *Atomic Energy Levels*, an NBS publication whose three volumes appeared between 1949 and 1958. With the discovery of lasers in 1960, this compilation achieved an importance which could not have been foreseen at the time of its preparation. If it had not existed in 1960, workers in laser research and development would have willingly paid 10 to 100 times the selling price to obtain the information contained in it. Prior to this time, however, the reasonable price enabled several thousand research workers and students in physics, chemistry, and astronomy to make use of this valuable reference source.

Another significant factor is the length of time over which the financial return will be realized. Although some data compilations remain current for only a few years, others have a useful lifetime of 10 or even 20 years. This presents no problem in an industrial laboratory. If there are convincing arguments that a data compilation will be worth \$1000 to a company over a period of 10 years, an initial outlay of \$50 is readily justified. However, the same is not true of a graduate student or young research worker. Even though he realizes the long-term value of the compilation to him, the \$50 price may be more than he can afford at the particular moment. The importance of distributing compilations of standard reference data among the younger workers in research and development has been emphasized many times. A requirement for full cost recovery would exclude much of this segment of the market.

We feel strongly that the intellectual efforts involved in the preparation of standard reference data should be covered by appropriated funds. It will be possible, we hope, to recover the editing and composition costs through a reasonable pricing policy. This philosophy is, in fact, entirely compatible with the situation which exists in publishing advanced scientific and technical books. If the retail price of a book reflected the full cost of writing it, including the salary of the author, most specialized scientific books (as distinct from elementary college textbooks) would be prohibitively expensive for the individual user. Instead, the author's university, company, or government agency subsidizes the book by allowing him to write it as part of his official activities. In some cases the subsidy is quite explicit; many books are written by university scientists on sabbatical leave, who are supported by private foundation or government funds specifically

granted for that purpose. This is an accepted mechanism for disseminating the knowledge of the nation's foremost scientists and engineers; the benefits of the system can hardly be questioned. We believe that the same policy is justified for standard reference data.

10. At what price do you expect standard reference data to be sold?

The data compilations issued so far through the GPO have been sold to the public at an average price of about 1.5¢ per page. The price of a single item thus varies from 25¢ to about \$5.00 (the latter for a 500 page table).

Our discussions with private publishers suggest a typical sales price of 4¢ to 5¢ per page for compilations issued through commercial channels. For some publications that might involve high manuscript preparation cost, the price may range up to 10¢ per page. We expect to recover about 15% of this through royalties.

It is too early to estimate the cost of data distributed in other forms such as computer tapes. One tape of a text-editing program is now being offered for sale at a retail price of \$100, of which about \$45 will be returned to NSRDS.

Mr. DADDARIO. This subcommittee will adjourn until the call of the Chair.

(Whereupon, at 11:37 a.m., the subcommittee was adjourned to reconvene at the call of the Chair.)





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