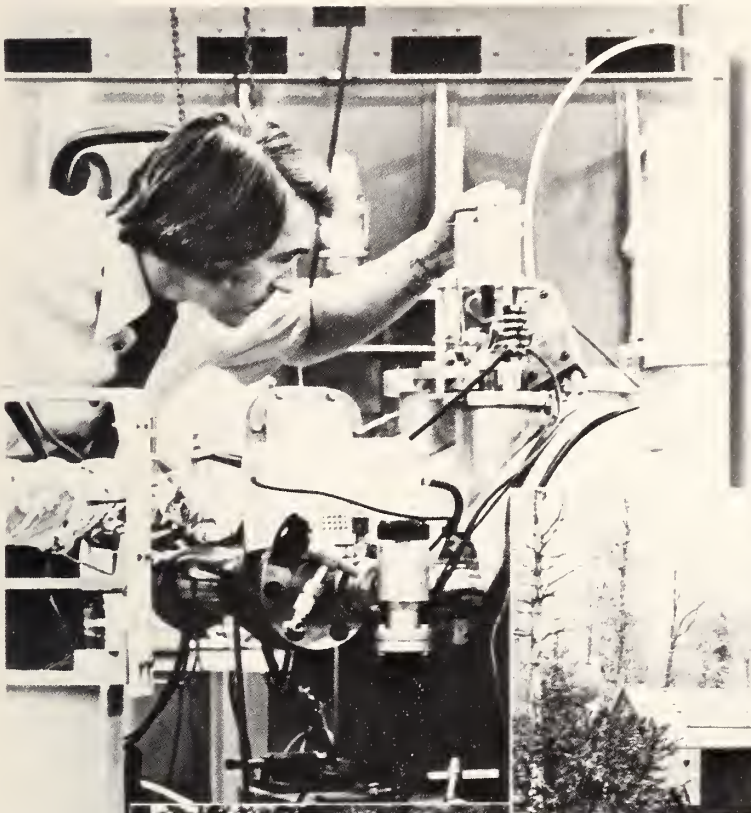
National Bureau of Standards

A National Resource for Science and Technology

Fiscal Year 1978



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JULY 1979

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Cover: Since 1901, the National Bureau of Standards has served as a national resource for science and technology—helping industry, government, academia, and the general public. On the cover are just a few of the activities and individuals aided by NBS research and services.

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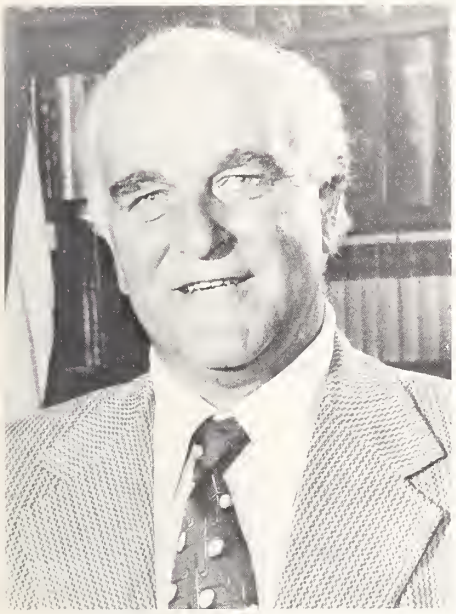


As the country's oldest national laboratory, the National Bureau of Standards started working on measurement problems just after the turn of the century. Seventy-eight years later, we are still providing the Nation with the scientific foundations needed for accurate measurements, and we are continuing to serve as a resource of technical support and advice for the Federal Government.

Science and technology have changed tremendously since NBS first opened its doors. Basic measurement science has become much more sophisticated, and our technical challenges have become increasingly complex and numerous.

In many respects, NBS has changed too. Judging by our expanded Congressional mandates and the variety of research areas we are engaged in, the need for the Bureau's research and assistance in solving national science- and technology-related problems has grown substantially.

We have tried to keep pace with the times and this country's needs, carrying out the scientific and technical tasks that are consistent with our multiple missions. This means that in addition to working to provide a better scientific basis for measurements, our researchers have been involved with the tasks of improving industrial productivity, promoting better materials use, using energy efficiently, and other societal challenges.

We have now launched a special effort to renew and enhance our technical competences in research areas critical to the Nation and basic to our goals. This strengthening of technical excellence is designed to ensure that the Bureau can continue to provide the underpinning essential to our ability as a Nation to make strides in top priority and emerging research fields.

Even as we build for the future, the Bureau is carrying out today's work. This report summarizes a number of significant NBS accomplishments during fiscal year 1978. There were, of course, many more. In fact, the Bureau is working on literally hundreds of projects at any one time.

One of our prime goals is to make NBS work more accessible to the Bureau's varied users in industry, academia, government, and the general public. We encourage you to ask for more details on Bureau projects. To help you use the information resulting from our research, an appropriate NBS laboratory or office is noted for each project cited in this report along with a list of selected publications. You will also find a Directory with names, addresses, and phone numbers. Feel free to call on us.

The headquarters of the National Bureau of Standards is located in Gaithersburg, Maryland.

NBS: A National Resource for Science and Technology

From the outset in 1901 when it was established by Congress, the National Bureau of Standards has been a national scientific and technical resource working in the public interest.

As the Nation's central reference laboratory for measurements in the physical sciences and engineering, NBS develops, maintains, improves, and disseminates hundreds of measurement standards. These include the fundamental standards relied upon for temperature, time and frequency, mass, amount of substance (mole), length, and electrical measurements. The methods for making these measurements and the standards themselves are needed by scientists, engineers, and medical practitioners, as well as business managers and consumers. These techniques and standards are used in thousands of ways each day, constituting the Nation's underlying measurement network.

Over the course of its 78 years, NBS has also been a technological problem-solver and an unbiased source of scientific and technological advice for the Nation. From the very start—and now more than ever before—the Bureau has used the technical know-how it has developed in meeting its measurement and standards responsibilities to answer problems that the Congress, other government agencies, or industry bring to it. Whatever the challenge, if it involves measurement in any way, NBS has probably been working on the answers—or helping others to find the solutions.

The Bureau is not a regulatory agency, so it does not mandate or enforce any standards. Rather, NBS provides the technical basis for the actual selection and application of standards by government agencies or domestic and international voluntary standards organizations.

A part of the U.S. Department of Commerce, the Bureau's staff of 3,150 includes a large contingent of scientists and engineers in just about every specialization, along with mathematicians, economists, architects, and professionals in a variety of other disciplines. This depth and breadth of expertise is one of the reasons why the Bureau has always been viewed differently and relied upon by a very diverse clientele in industry, government, and academia.

- To research scientists in university, corporate, or government laboratories, NBS is a source of reference materials, data, and standards that are needed to calibrate equipment, make essential calculations, or improve measurement techniques.

- To engineers involved in product or system design—whether it be a waste incineration plant, a super-sensitive microelectronic device, or an energy-efficient refrigerator—the Bureau is an authoritative distributor of technical guidelines and standards.

- To Federal and local government officials administering energy, materials, or any number of research programs, the Bureau is an independent laboratory that performs research with objectivity and technical soundness. To those making decisions about consumer protection, environmental quality, and public safety regulations, NBS is an

At left, physicist Louis Holdeman describes the NBS electrical measurements facilities to a delegation from the Peoples Republic of China. Above, DOC Assistant Secretary for Science and Technology Jordan J. Baruch and members of the delegation look on as Robert Crowder demonstrates NBS literature retrieval operations.

unbiased source of technical information upon which those decisions can be based.

- To State and local officials responsible for assuring buyers and sellers that a pound is a pound, a gram is a gram, or a liter is really a liter in businesses throughout their jurisdictions, NBS is the measurement agency that provides uniform sets of weights and measures, technical training, and management assistance.

- To American voluntary standards organizations seeking the technical information needed for writing product or system standards, the Bureau is a resource for science and engineering data.

- To international groups concerned about the compatibility of measurements and standards among nations, NBS is the primary U.S. contact point for exchanging information and bringing about that compatibility.

- To the public at large, the Bureau is a source of consumer information on topics such as energy conservation, corrosion, smoke detectors, and many other subjects. And while individuals may not realize it, the public also benefits directly from Bureau research in such varied areas as improved clinical chemistry analysis for medical diagnosis and environmental protection.

Reexamining, Streamlining

To an unprecedented degree, the mission, resources, and future directions of NBS were the subjects of public attention during fiscal year 1978 as a variety of organizations took searching looks at the Bureau. Congress gave special consideration to the agency: the first Congressional oversight hearings in recent memory were held in the Senate and, for the first time in 6 years, in the House of Representatives. The Congressional Office of Technology Assessment also reviewed NBS, as did the Bureau's Visiting Committee and the agency's management itself. There was a thorough examination of the institution's present condition, its strengths, and the areas in which it should devote greater attention in order to perform today's tasks and prepare to meet the science and technology challenges of the future.

A major subject of the evaluations was the growth in responsibilities and short-term projects which NBS has undertaken as a result of Congressional assignments and government agency requests. In step with a resurgence of concern about the Nation's scientific and technological health and capacity to innovate, there was a reassessment of the traditional NBS role in performing basic scientific research and providing the country with a core of technical competence in the most advanced measurement sciences and sophisticated technological applications.

As a result of the assessments both within and outside the Bureau, NBS made a number of organizational and program changes designed to keep itself at the leading edge of science and technology and to make sure that it remains a source of technical excellence for the Nation.

During the fiscal year, NBS underwent its first major reorganization in more than a decade. Designed to help the Bureau in its multiple roles as the Nation's central measurement laboratory, basic research performer, and technological problem-solver, this organizational shift replaced the separate Institutes of Basic Standards, Materials Research, and Applied Technology with a new National Measurement Laboratory and a National Engineering Laboratory. There was also a minor realignment of the Institute for Computer Sciences and Technology. (A directory of the new organizational structure is provided on page 83.)

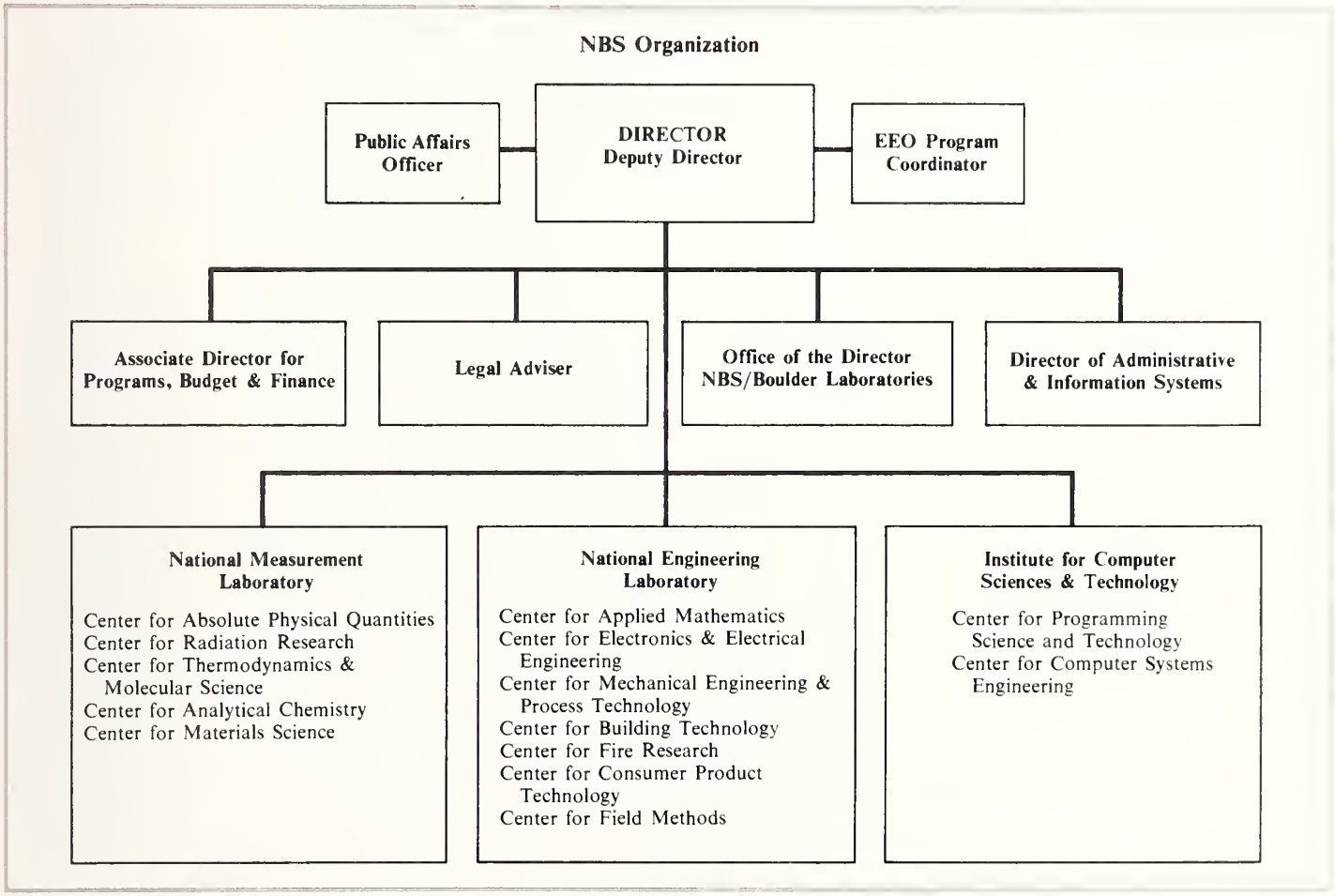
The Bureau is now more clearly organized along disciplinary and functional lines. Technical competences that had matured and grown over the years in various organizational units have been consolidated. The number of formal operating units also has been reduced.

The regrouping is helping the Bureau to match its capabilities with its diverse responsibilities. By permitting more flexible use of the technical competences lodged within NBS laboratories, the organizational streamlining also facilitates the interdisciplinary research needed in dealing with today's scientific and technological issues. The NBS mathematical capabilities now located within the National Engineering Laboratory's Center for Applied Mathematics, which helps all segments of the Bureau meet the expanding mathematical needs inherent in advanced research, exemplify the benefits of this flexible organizational setup.

Enhancing Technical Excellence

The reorganization reflects the desire to maintain and enhance the technical resources of the Bureau, especially in areas likely to require more attention in the future as national scientific and technological priorities and needs change.

The Bureau must have the required technical expertise and facilities on hand, not only to respond quickly and effectively to requests for immediate assistance on urgent technological problems, but also to carry out the basic measurement and fundamental scientific research functions of the agency. Recent measurement research within the NBS Center for Absolute Physical Quantities is a case in point.

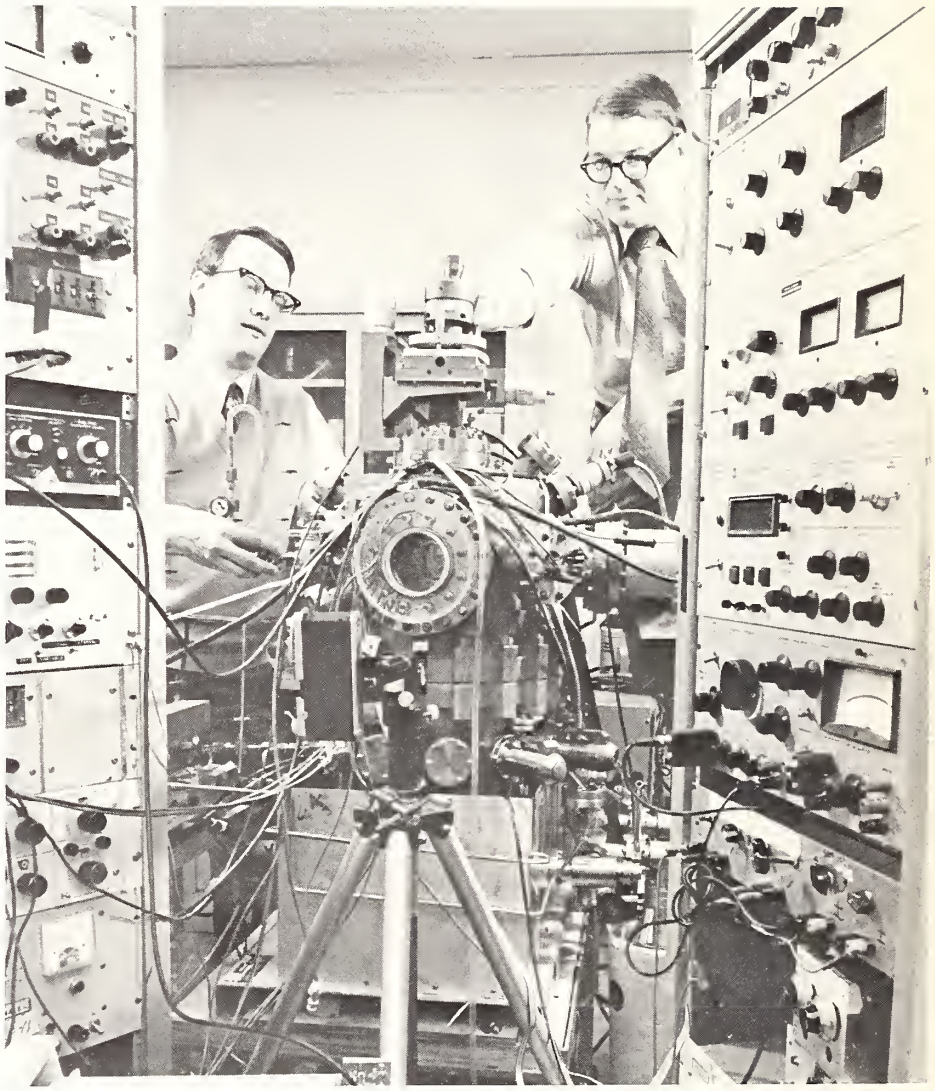


Measurement standards based upon the atomic frequencies of particular elements have become increasingly important to those who need the most precise possible values for the basic physical constants. The present measurement standard for the second, for example, is based upon the frequency of radiation emitted by a cesium atom. (One second now is defined as the time required for 9,192,631,770 oscillations of the "undisturbed" cesium atom.) Although they are the best standards available, all atomic frequency standards are limited in accuracy mostly because the motion of the atoms gives rise to frequency uncertainties.

Last year, NBS scientists were able to confine individual atoms in a trap and then "cool" the atoms by using laser radiation. This slowed down the atoms and reduced the frequency uncertainty. The new cooling technique will allow very high resolution spectroscopy of atoms and molecules that should permit a better general understanding of molecular structure and may lead to greatly improved definitions of the units of time and length. The basic competences in physics making this experimental breakthrough possible were acquired and cultivated at NBS during the past several years and required careful planning.

The Bureau's ability to fulfill its multiple missions and provide the measurement foundations for technological innovation is heavily dependent on the continued maintenance and enhancement of its technical competence. Thus, NBS last year embarked on a program to strengthen key research areas. This competence enhancement program will enable NBS to attain its own goals and to meet the projected needs of those who depend on Bureau services. Research fields selected for this multi-year program will involve long-term theoretical and experimental studies upon which NBS and its clients can rely for expertise. Special competence building initiatives are being undertaken where scientific solutions compatible with the NBS mission appear possible and where the underlying scientific foundation appears ripe for advancement.

Electron Stimulated Desorption Ion Angular Distributions (ESDIAD) is a new method for directly determining surface molecular structure. Researchers Theodore E. Madey (left) and John T. Yates, Jr., are shown with ESDIAD apparatus, one of several new measurement tools developed in the Bureau's surface science program.



Visions of the Future

Surface science, one of the fields selected for the first installment of the special competence enhancement program, illustrates the fundamental importance and nature of the research areas being given this special attention.

Even as great strides have been made over the past decade in understanding the electronic and chemical properties of surfaces, it is apparent that there is much more to be learned about the surfaces of materials. Our ability to understand and control processes in such diverse areas as catalysis, adhesion, corrosion, lubrication, frictional wear, bonding, and oxidation and our use of an array of technologies, including microelectronics and many energy production processes, rests upon advances in surface science. Our understanding of the smallest particles deemed to be pollutants and certain biological processes also stands to be affected by progress in this multidisciplinary research field.

Surface science, which relies heavily upon the joint work of physicists and chemists—both theorists and experimentalists—is an area of basic research at the frontier of science, but one which holds extraordinary opportunity for practical applications.

The properties of surfaces are known to differ from the properties of the bulk of many materials. To a great extent, these surface properties are determined by the chemical identity and the position of individual atoms and groups of atoms at or near the surface. Scientists working in this field are seeking to understand surface properties and processes at the atomic level. One of their principal challenges is to develop improved measurement methods with the sensitivity, specificity, and accuracy needed to identify surface atoms and atom arrangements in both laboratory and practical situations.

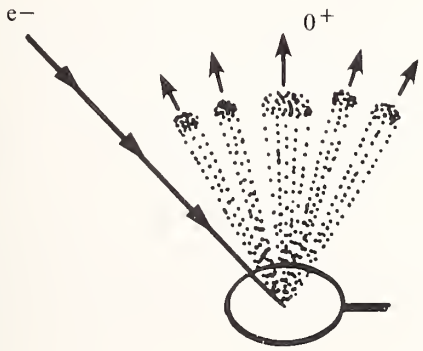
NBS scientists are now at the forefront of current understanding and abilities in surface science. In both the National Measurement Laboratory and the National Engineering Laboratory, the Bureau last year conducted a number of projects that have brought a more complete understanding of surfaces and will stimulate improved application of this knowledge to industrial processes and technologies dependent on surface characteristics.

For instance, recent work in the Center for Thermodynamics and Molecular Science, a unit which has been heavily involved in surface science research, led to the development of a method for directly determining the geometrical structure of molecules adsorbed on surfaces. The Bureau researchers have used this technique of determining the angular distribution of ions desorbed by electron impact (ESDIAD) to make the first such measurements.

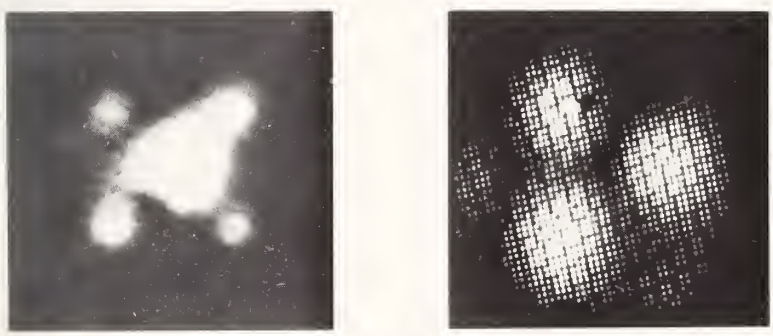
In the ESDIAD method, a focused electron beam bombards a metal single crystal containing an adsorbed layer of gas. Top shows desorbing oxygen ion (0^+) beams during bombardment of an oxygen-covered tungsten single crystal. 0^+ beams are detected with image intensifier and displayed visually on a fluorescent screen. Photos show patterns of 0^+ emissions as viewed on screen. At bottom are two different atom arrangements of the tungsten surface, corresponding to photos. This example illustrates a direct relationship between ion desorption directions and the orientation of surface molecular bonds that are ruptured by the electron beam.

ESDIAD Apparatus

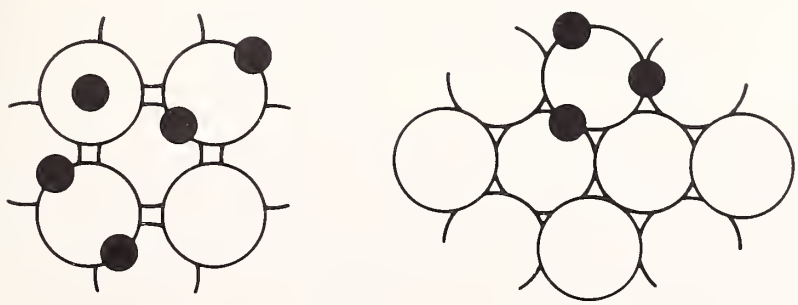
Electron Stimulated Desorption Ion Angular Distributions (ESDIAD)



Schematic view of microscopic process shows desorbing oxygen ion beams during bombardment of an oxygen covered tungsten single crystal



Patterns of oxygen ion emissions as viewed on fluorescent screen.



Top view of tungsten surfaces (black circles represent adsorbed oxygen atoms).

Also in this Center, NBS scientists showed that a nickel single crystal could accurately model the practical, high-surface area powder nickel catalysts used in the production of methane (synthetic natural gas) from hydrogen and carbon monoxide. The nickel single crystal is relatively easy to characterize, so the researchers can readily study at the atomic level the effects of catalytic poisons and promoters on this important reaction.

A National Academy of Sciences panel has said that "Surfaces and interfaces are possibly one of the most fruitful research topics in materials science. Knowledge at the most fundamental level in this area can be expected to be relevant to almost all uses of materials..." By building upon the base of technical competence which already exists at the Bureau in surface science and surface-important technologies, NBS will be able to contribute significantly to scientific understanding and a multitude of technological applications important to society and to the NBS mission.

Surface science is just one of several research areas chosen for the competence enhancement program for fiscal year 1979. The other fields include: nonlinear convection and smoke dynamics, organic electrochemistry, small angle neutron scattering, wave optics, crystal defect physics, and fluid mixtures models.

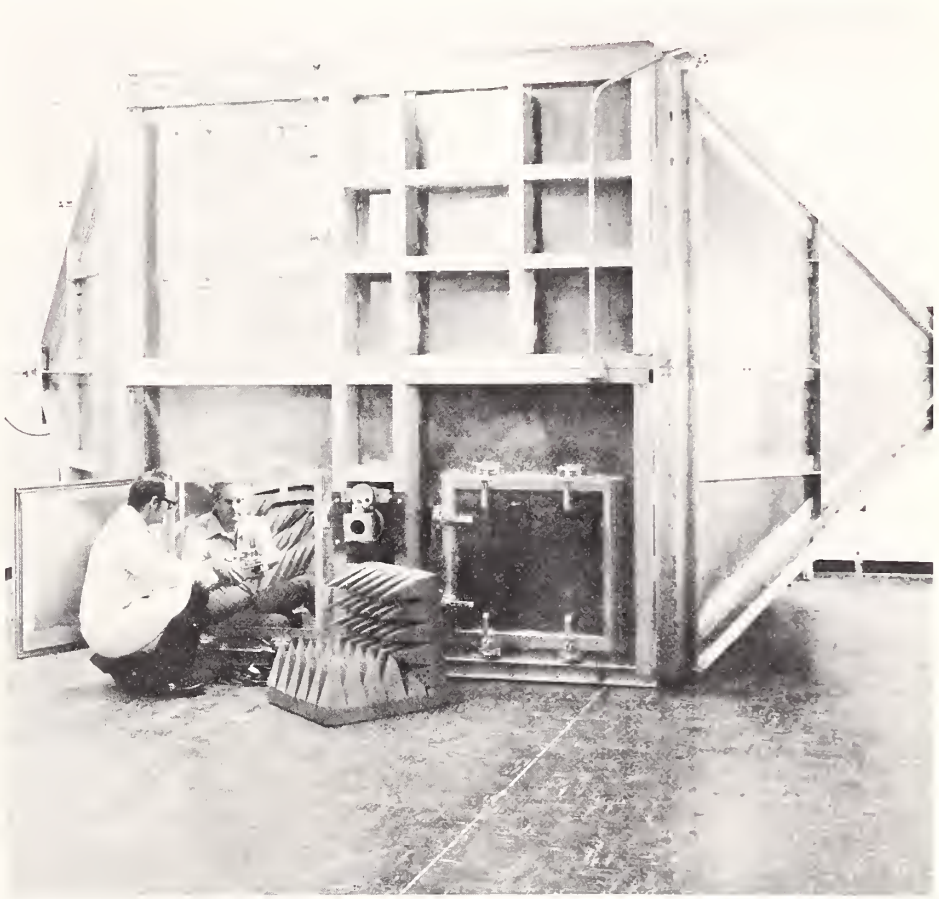
Each of these areas—and those still under consideration for special emphasis in the coming years—can be expected to pay dividends in the form of future science and technology advances by the Bureau and others throughout the Nation. Our vision of the future is expanding, and NBS is making a determined effort to prepare for it.

Increasing Measurement Capabilities

The following pages highlight and explain some of the most significant NBS achievements of fiscal year 1978. In one way or another, each of these projects represents an effort to increase productivity, improve the quality of life, or advance our ability to comprehend more completely our earthly and universal environment.

These multiple purposes of NBS research are especially apparent in the Bureau's efforts to increase measurement capabilities, for that is a goal which lies at the heart of nearly all NBS activities.

Electronics engineer Myron L. Crawford (left) hands a piece of electronic equipment to technician John L. Workman, who is inside the Bureau's Transverse Electromagnetic Cell. The specially-developed cell tests equipment for susceptibility to electromagnetic interference, a phenomenon of growing concern.



The Electromagnetic Interference Challenge

Last year, an American electronics firm that was having trouble selling its products in West Germany came to the National Bureau of Standards for help. NBS does not offer marketing services, but the Bureau does offer a range of expertise in the measurement of electromagnetic radiation and interference and that is precisely what the electronics manufacturer needed.

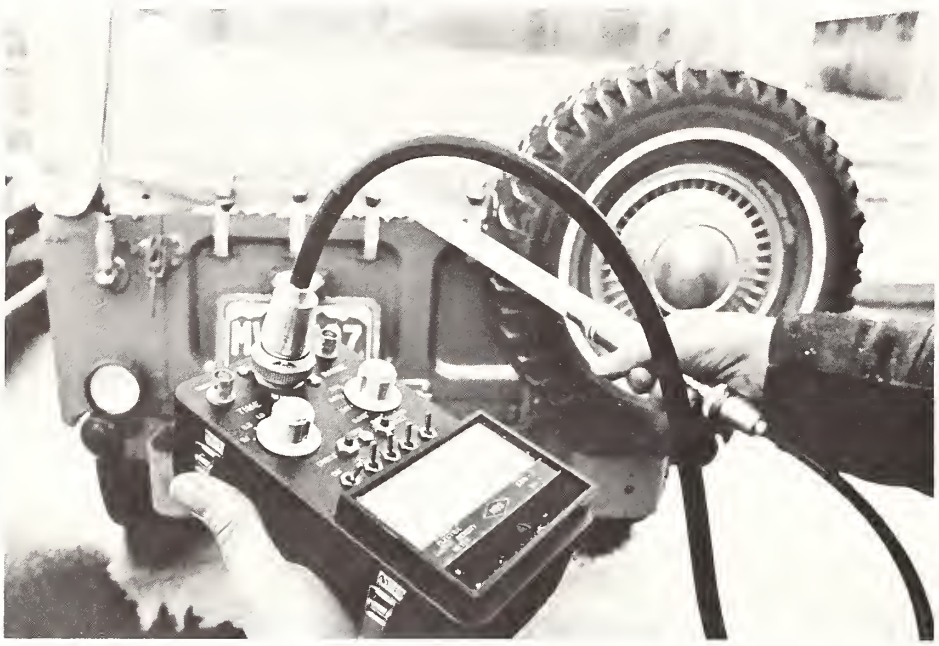
Electromagnetic interference, or EMI, occurs when electromagnetic radiation interferes with the operation of electrical or electronic equipment. The major difficulty is caused not by ionizing radiation like x-rays—which present their own benefits and hazards—but by non-ionizing radiation. This sort of radiation is emitted by a multitude of consumer, industrial, and communication products. CB radios, microwave ovens, high voltage transmission lines, and radio and TV transmitters are just a few of the many sources of electromagnetic radiation in the United States today.

While we do not yet have a full picture of the EMI situation, the effect of such radiation on electrical and electronic products is of growing concern. A CB radio transmission from a passing car might conceivably trigger blasting charges at a roadside construction site. Interference to radio and television reception can be caused by CB, amateur, and other radio operations. Consumer products have been known to malfunction as a result of EMI. Some electrical and electronic disorders stemming from EMI can indirectly pose public health and safety hazards. For instance, anyone with a heart pacemaker should be warned to stay clear of microwave ovens which might interfere with the pacemaker's sensitive controls. As new electronic products are introduced, the opportunities for disruption and damage due to EMI increase.

Dean G. Melquist, an electronics technician with the NBS/Boulder laboratories, checks the electromagnetic radiation pattern of a waveguide horn in a newly constructed anechoic chamber.

The heart of the EMI problem is that there is an inadequate base of measurement techniques for establishing either the total electromagnetic environment at any point in time or the susceptibility of electronic systems to that environment. In the case of the U.S. electronics firm, a desk-top computer it wanted to sell in West Germany had been rejected by that country for failing to meet German standards for controlling electromagnetic radiation—despite the fact that the company's own measurements

The probe shown here is being used to measure the radio frequency level around a CB antenna mounted on a vehicle. NBS is working to resolve the measurement uncertainties associated with electromagnetic radiation emitted by and affecting CB radios and a multitude of other consumer, industrial, and communication products.



indicated that the product met the applicable standards.

The firm approached NBS for assistance in resolving the apparent measurement discrepancy. The Bureau has extensive facilities for measuring electromagnetic radiation, including the only U.S. facilities similar to those used by the Germans. It also has a technical staff known for its experience in closely related measurement areas.

The manufacturer entered into an agreement with NBS and initiated a Research Associate Program at the Bureau. (The NBS Research Associate Program enables technical specialists in U.S. firms and professional organizations to work at NBS temporarily in order to carry out projects of mutual interest. More information about the program can be found on page 68.) The program brought company engineers to the Center for Electronics and Electrical Engineering at the NBS Boulder, Colorado, laboratories.

Through this joint effort, NBS and the electronics firm have been trying to pinpoint and explain the measurement discrepancies. The results of their investigations will be published and distributed by NBS. The likely end product? The company may yet be able to sell its products in West Germany, and other U.S. manufacturers will have ready-made measurement procedures for similar situations. This will help not only individual companies, but it will also mean a stronger American export position at a time when our trade balance is of utmost importance. It also may mean that American consumers will be able to purchase products that have less potential for exacerbating the EMI problem in this country.

NBS also aided another U.S. firm last year with a specific EMI measurement problem. A major communications and electronics company needed to test electronic telephone equipment for its susceptibility to EMI. Once again, the Center for Electronics and Electrical Engineering was called upon, this time to construct a transverse electromagnetic (TEM) cell for the company. A TEM cell is basically a large enclosure where electronic equipment can be tested to see how it is affected by known sources of EMI or to check its own electromagnetic radiation output. NBS constructed the first such testing tool several years ago, just one of a variety of instruments the Bureau has developed to measure EMI radiation and its effects.

The Bureau does not normally build laboratory equipment for a private company. But in this case, NBS decided that the demand for TEM cells would be growing as a result of the increased awareness of EMI and that the Bureau's guidance on building the cells would become more important. Six months after they started on the project, NBS engineers and craftsmen had built and shipped the custom-made cell to the company. Records documenting cell design and construction were maintained as work proceeded. Those step-by-step guidelines will now be made available to any firm or laboratory that wishes to build its own TEM cell.

As the premiere government agency for electromagnetic radiation measurement, NBS also provides considerable assistance to other Federal agencies that are concerned with EMI. Last year, NBS developed four devices to help guard sensitive military electronics equipment from EMI which can jeopardize control systems. Under certain conditions of interference, it is conceivable that a weapon might not be deployed or detonated when expected. The devices NBS invented after several years of work for the U.S. Army Communications Command will sound an alarm when high levels of electromagnetic radiation are detected. Sensitive components of the sophisticated military hardware can then be shielded or the radiation source can be tracked and eliminated.

The National Highway Traffic Safety Administration has been aware of the possibility that EMI could cause failures in the electronic controls of anti-skid braking systems used in trucks. In fact, a regulation which led to the installation of such electronic anti-

Bolstering State Weights and Measures

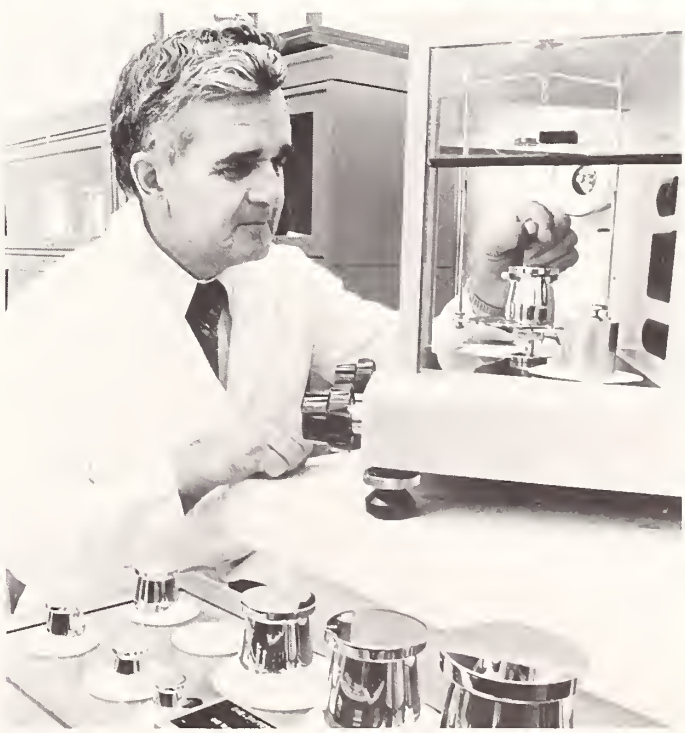
The responsibility for ensuring the accuracy of weighing and measuring equipment used in the U.S. marketplace falls to individual states and territories, making their weights and measures offices the first line of defense against chaos in the marketplaces and exchanges of this country.

In the early 1960's, NBS officials surveyed various State weights and measures offices and laboratories and found serious weak points in that measurement system. They discovered that many of the State standards were in disarray. Certain sets of standards could not even be physically located. That was not too surprising, since the last official sets of standards had been distributed to the States during the middle of the 19th century.

As custodian of the national standards of measurement and as the organization which sponsors and assists the National Conference on Weights and Measures, NBS in 1965 began a program to distribute a complete set of replacement standards to the States and territories.

Under the replacement program, weights and measures offices received 67 different mass standards (weights), 4 steel rules for length standards, 17 standards for volume, and 5 precision balances. NBS also trained weights and measures personnel in the operation and maintenance of a modern standards laboratory.

Last year, NBS moved into the final phase of its 13-year program when it presented sets of standards to Washington and Mississippi. (The Virgin Islands and Puerto Rico have since received their standards also, completing the weights and measures program for 53 States and territories.)



NBS instrument maker Jeffrey Kelley (top) uses a numerically-controlled lathe to fashion a 5 kilogram mass standard designed for use by states and territories. At right, engineering technician Blayne Keysar tries a standard mass of 5 kilograms in a precision balance.

An NBS experiment has helped resolve discrepancies surrounding quantum electrodynamics, a basic theory of physics. Physicists Albert Henins and Ernest Kessler (right) discuss the project, which has led to a hundredfold improvement in the overall accuracy of electromagnetic wavelength standards in the gamma-ray region.

skid systems was withdrawn when the seriousness of the EMI problem was raised as an issue. In recent tests for that agency in which trucks with electronically-controlled brakes were exposed to an electromagnetic radiation field, NBS engineers confirmed that EMI affected the operation of the brakes. Additional research is continuing to determine the extent of the problem.

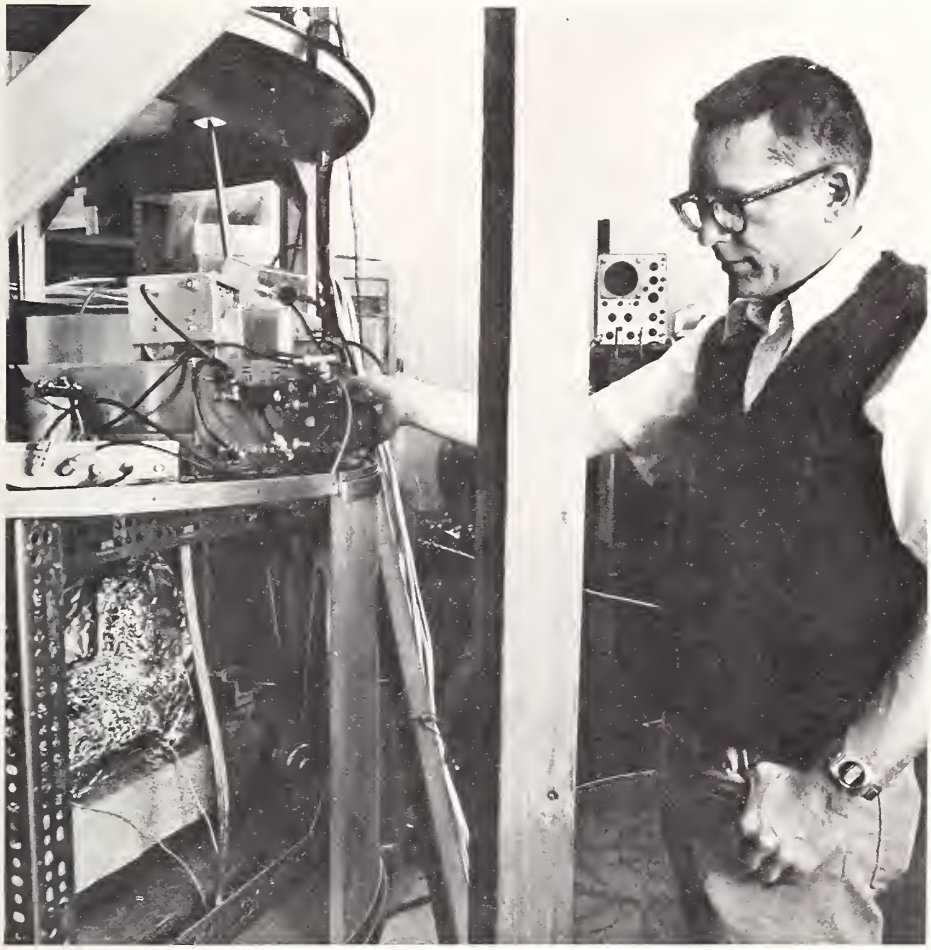
Also last year, NBS completed work for the Federal Aviation Administration on specialized measurement instrumentation and techniques to assess electromagnetic radiation levels around antenna sites at airports and in airplanes. Bureau researchers also supplied NBS-developed instrumentation to assist the Environmental Protection Agency in developing a data base characterizing electromagnetic radiation in 12 major U.S. cities. The aim was to provide a benchmark which will help judge the state of the electromagnetic environment over a number of years.

Considering the rapidly mushrooming reliance on electronically controlled products emitting and simultaneously standing to be affected by electromagnetic radiation, the Bureau's EMI measurement research and information is certain to become more important.

Progress in Basic Research

A number of measurement studies at NBS fall into the realm of basic science. In this category is a whole range of investigations aimed at studying the fundamentals of physics by applying accurate measurements. These experiments strengthen the foundations of our measurement system, but they are first and foremost designed to improve our knowledge of physics by testing basic principles and theories. They are part of the mandate in the NBS Organic Act to undertake "the determination of physical constants and properties of materials when such data are of great importance to scientific or manufacturing interests and are not to be obtained of sufficient accuracy elsewhere."

Recent Bureau research in measurement science has improved upon the 1887 "Michelson-Morley" experiment which aided Einstein and others in developing the special theory of relativity. Physicist John L. Hall is shown here with some of the laser equipment which helped to achieve this increased accuracy.



This type of basic research is exemplified by the work of physicists in the Center for Absolute Physical Quantities who have been characterizing the electromagnetic spectrum to a greater degree of accuracy than has been achieved previously. Using a combination of x-ray and optical interferometry followed by accurate determination of gamma-ray diffraction angles, these NBS physicists have established new wavelength standards in the gamma-ray region that are more closely tied to basic atomic standards in the visible region. Their achievement represents a hundredfold improvement in the overall accuracy of electromagnetic wavelength standards.

The new scale has already had several important applications. For instance, it has aided other scientists in resolving persistent conflict between experiment and theory involving certain exotic atoms containing mu mesons. This discrepancy had led to a questioning of one of the most basic theories of modern physics, quantum electrodynamics (QED). At the root of this experiment-theory discrepancy was the inconsistency of the wavelength standards in this part of the electromagnetic spectrum. Using NBS research results, scientists have been able to bring about greater agreement between experiment and theory, thereby supporting QED. In a second application of the NBS work, other scientists have compared the radiation emitted by atoms containing a pi meson to the new NBS wavelength standards, enabling them to calculate the pi meson mass more accurately.

Another test of QED theory also was made possible last year as a result of an improved measurement method for determining the proton gyromagnetic ratio to the unprecedented accuracy of two parts in ten million. When combined with the measured values of other fundamental constants, this new result yields an extraordinarily precise value for the fine structure constant, a critical parameter in QED. This has helped permit the unequivocal comparison of QED theory with experimental observation and will allow testing of theory and experiment for several basic quantities at heretofore unattainable accuracies.

Like much of the research NBS performs in measuring fundamental physical constants, this work by the Center for Absolute Physical Quantities required unique capabilities. In this case, a first-class nonmagnetic laboratory and expertise in ultraprecise dimensional metrology were prerequisites. Both are unique to NBS in this country. In fact, this is clearly an experiment which no one else in the United States could have undertaken. At least four other countries have had programs dating back 10 to 20 years to determine the proton gyromagnetic ratio. The NBS results improved by a factor of 20 the previous level of accuracy achieved elsewhere.

A new version of this experiment which should yield an additional factor of 10 increase in accuracy is now underway and several measurement spinoffs should result. For example, methods for measuring the physical dimensions of objects at cryogenic temperatures, techniques for determining the load coefficients of precision resistors to high accuracy, and a means to generate, measure, and control magnetic fields to unprecedented

The Bureau's International Scope

As the national measurement laboratory of the United States, NBS is a prominent member of the international research and standards communities. The Bureau is actively involved in several international standards-setting organizations, including the International Bureau of Weights and Measures, the International Organization for Legal Metrology, and the International Standards Organization.

Outside of this formal standards arena, the Bureau also has direct contact with individual standards and research organizations in developed and developing countries around the globe. This liaison facilitates the intercomparison of a variety of measurement standards and allows NBS to share in the latest world developments in science and technology.

Another facet of the Bureau's international role is its assistance to other Federal agencies in policymaking on international science and technology issues. Last year, for instance, NBS helped the Department of State to prepare for the 1979 United Nations Conference on Science and Technology for Development. This conference—the first of its kind since 1963—covers several aspects of the use of science and technology to benefit developing countries.

The Bureau works frequently on a one-to-one basis with scientists and engineers from other countries. For example, NBS last year hosted 42 guest workers from 17 countries who participated in a broad range of research projects. This international exchange allows the Bureau to draw upon the expertise of researchers around the world and offers foreign scientists and engineers an opportunity to become directly involved in studies at NBS. (For more information on this and other exchange programs, see page 66.) This science and technology sharing is enhanced further by representatives of foreign governments, standards-writing organizations, and industries who visit the Bureau's laboratories. During FY 1978, NBS received 695 such visitors from 55 nations.

accuracy and precision are just a few of the prospects.

Over the years, NBS has helped usher in a revolution in measurement science and in our ability to test fundamental physical theories through application of laser technologies. Using new laser-stabilization techniques they had developed, physicists at the Joint Institute for Laboratory Astrophysics (JILA)—operated by NBS and the University of Colorado—last year reconfirmed and improved upon one of the seminal experiments fundamental to scientific knowledge about time, distance, and motion.

Known as the Michelson-Morley test of "ether drift," this famous 1887 experiment has been basic to the development of the special theory of relativity by Einstein, Lorentz, and others. In part, this theory holds that space is isotropic—that is, the same in all directions. In 1964, Massachusetts Institute of Technology scientists Townes and Javan demonstrated that the accuracy of that experiment could be increased by using laser measurement technology.

With the assistance of a guest worker from the Laboratoire de l'Horloge Atomique in France, JILA physicists have developed and put new laser stabilization techniques to work in dramatically improving upon the earlier tests of isotropy. The recently achieved results represent a 4,000-fold improvement over the 1964 experimental accuracy. With sufficiently sensitive measurements of this type, it may be possible in the future to actually measure the effects of the curvature of space due to the gravitation of massive bodies, such as the earth or the sun.

Much of the basic research at the Bureau not only adds to our fundamental scientific knowledge base, but also finds specific—and many times diverse—applications in science and technology.

A number of recent achievements in the Center for Thermodynamics and Molecular Science illustrate this type of research. A prime example is the application of a technique (ion-cyclotron resonance) which can be used to measure the thermodynamic properties associated with the transfer of electrons in mixtures of gaseous organic compounds. This method has relevance in comprehending not only the chemical processing of hydrocarbons but also the behavior of certain dynamic biological processes like photosynthesis.

Similarly, recent accomplishments in explaining the process whereby the chemical bonds joining carbon atoms to each other are split apart have their roots in the most basic NBS molecular science and measurement skills. This work in the Center for Thermodynamics and Molecular Science holds clear promise for important applications in controlling and optimizing the way fossil fuels perform during combustion.

Another achievement by scientists in that center exemplifies the multiple directions in which basic research can lead. By studying the millimeter-wave spectrum of glycine in its vapor phase, NBS scientists resolved years of conjecture among chemists and biologists about the geometrical form glycine vapor takes. More detailed studies now made possible by the NBS research are expected to yield information which will be useful in modeling biochemical reactions of amino acids, the building blocks of proteins. At the same time, the results are already being put to use in a search by radioastronomers for glycine in interstellar molecular clouds. Discovery of biological molecules such as glycine could revolutionize our current ideas about the origin and natural evolution of life.

Measurement: The Bureau's Forte

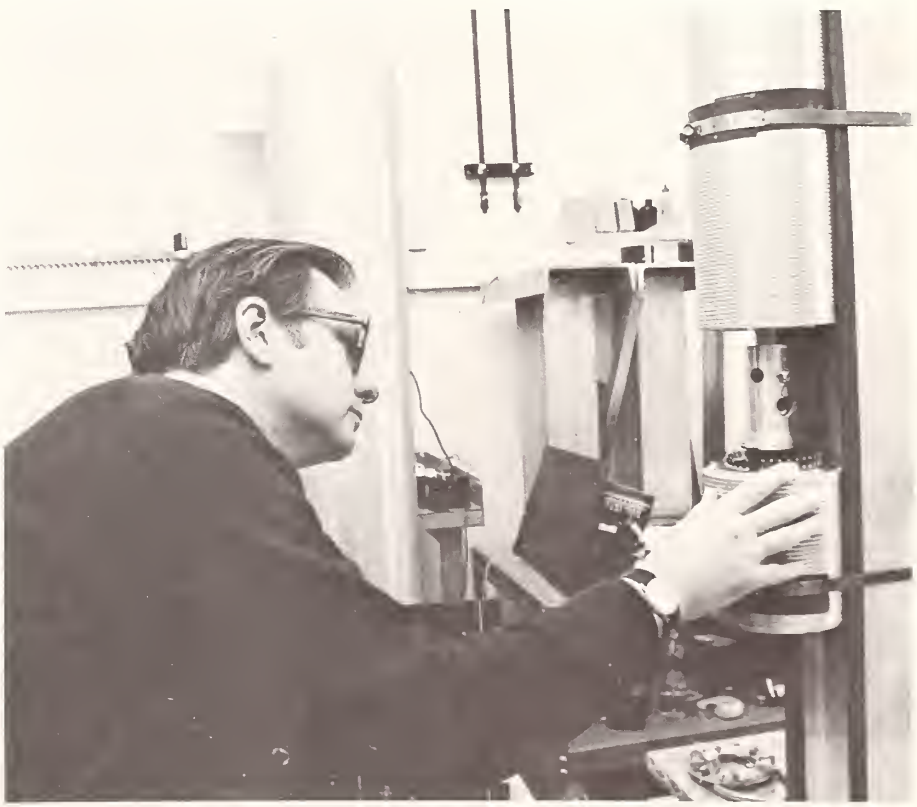
In addition to those projects cited elsewhere in this report, some of the other significant NBS achievements of the past year which increase the Nation's measurement capabilities are noted below.

Scientists in the Center for Thermodynamics and Molecular Science:

- developed a new way to "fingerprint" liquid fossil fuels, including gasolines, fuel and machine oils, and industrial hydrocarbon solvents. Utilizing photoionization mass spectroscopy, the technique can be used by police laboratories to compare such fluids and by scientists and engineers who need to know more about the characteristics of alternative fuels like shale oils and coal liquefaction products.
- introduced a new factor to be considered in modeling the ionosphere by developing a novel technique (threshold photoelectron spectroscopy) to analyze chemicals believed to be similar to those found in that portion of the atmosphere, but which are not ordinarily observable because of their low concentration.
- made measurements of the thermodynamic properties of rapidly heated graphite in a study supported by the U.S. Air Force. These measurements will provide the Air Force with information about graphite employed as a heat shield material for rockets. They will also improve understanding of the performance of fuel and structural solids in nuclear reactors.
- established a service for calibrating low and medium vacuum measurement instruments. This service provides an accuracy 10 to 100 times greater than previous services and is being used extensively by industry.
- improved the equation that describes the pressure-volume-temperature relationships of ethylene, a chemical widely used in industrial applications. This was accomplished as part of a joint government-industry program administered by the Bureau's Office of Standard Reference Data.
- constructed a "spherical acoustic resonator" filled with certain gases and analyzed its sound characteristics in order to obtain highly accurate measurements of the thermodynamic properties of these gases.

Scientists in the Center for Absolute Physical Quantities:

- determined that time and frequency information from a satellite system that NBS helped to initiate in 1973 can be corrected for geographical location to an accuracy better than 20 microseconds, providing users with accurate information regardless of their location.
- demonstrated a technique by which the accuracy of today's cesium standards—which serve as the international basis for the definition of the second—may be improved by a factor of 10. This improvement would have a great impact in rapidly expanding use of such standards for position location, collision avoidance, and communications applications.
- developed a device, called a "super spring," that will help isolate equipment from the disturbing influence of vibrations as low in level as the earth's natural microseismic background activity.
- established a new way to calculate the rotational and vibrational energy levels of spherical-top molecules, greatly simplifying the analysis of high resolution



NBS physicist James E. Faller checks out the new "super spring," a device for mechanically isolating sensitive equipment from extremely low-level vibrations. The super spring was developed at the Joint Institute for Laboratory Astrophysics, a research organization operated by NBS and the University of Colorado.

Measurement: The Bureau's Forte (continued)

spectra. The new method will help researchers studying laser isotope separation, time and frequency standards, and laser-induced chemistry.

- participated in an international comparison of ac-to-dc transfer standards. These standards play a critical role in verifying the performance and accuracy of ac test and measurement instrumentation. U.S. standards were found to be in excellent agreement with those of the U.S.S.R., Japan, and the United Kingdom.

- achieved a stability of two parts in one billion in a room temperature LC resonator, a device for controlling frequency. By far the most accurate in the world, this device opens up a new level of sensitivity for inductance and capacitance measurements and has potential for application to temperature, pressure, magnetic susceptibility, and displacement measurements.

Scientists and engineers in the Center for Mechanical Engineering and Process Technology:

- designed and developed a new low-velocity airflow facility which can produce a uniform airflow with minimal turbulence at velocities as low as 3 meters per minute. Laser-optic methods are used as the primary velocity standard. In a series of tests, a number of anemometers were evaluated for the U.S. Bureau of Mines. These results will help establish accurate safety standards for mine ventilation. The same facility also allowed NBS to serve as a third party resource for the General Services Administration and a private contractor, demonstrating that precise specifications for ventilation in a new multimillion dollar office building were feasible.

- developed a new "Facility for Analyzing Surface Texture," which will aid in characterizing the topography of high-performance optical surfaces and assist in research designed to extend the lifetimes of gyroscope bearings by improving measurement of surface finish. The facility also has been used to study the wear in communications satellites' electrical contacts and to help judge specimens used as Standard Reference Materials for calibrating instruments in the machine tool and other industries.

- measured the thermal expansion properties of crude and refined petroleum drawn from approximately 400 sources around the world. These measurements are crucial to the computation of petroleum volumes and thus to the value of shipments. The work was accomplished with the support of the American Petroleum Institute.

- developed mathematical models that have greatly improved our understanding of the fundamental operation of industrial flowmeters, which are used to measure liquids and gases ranging from water, sewage, and oil to natural gas and air. Errors and uncertainties in flow measurement are becoming increasingly important, especially in the metering of liquid fuels where small percentage errors can make a difference of substantial sums of money.

Scientists and engineers in the Center for Electronics and Electrical Engineering:

- completed measurements on the largest antenna ever evaluated by near-field scanning techniques which were developed at NBS. There are no conventional (far-field) means for measuring an antenna of this size to the required accuracy. The new NBS measurements will help calibrate earth terminals of satellite communication systems.

- developed a new method, known as the "six-port" technique, that is likely to have a major impact on the design of equipment that automatically records microwave and high frequency measurements. More accurate, simpler, and less costly than traditional methods, the Bureau's innovation will permit microwave specialists to tailor their measuring equipment to their particular requirements rather than procure a general-purpose instrument with excess measurement capabilities. The transfer of this technology was facilitated by a Research Associate Program sponsored by a major aerospace and data communications system manufacturer.

- used radio stars as a standard signal source to make high accuracy measurements of satellite-earth terminal sensitivity at extremely high frequencies (above 6 gigahertz). These measurements will become increasingly important as commercial communication satellites move into these higher frequency ranges in the early 1980's.

- compared electrical energy measurement standards of the United States, West Germany, and Canada, revealing previously undetected systematic errors and pointing to a need for periodic comparison. High accuracy is essential in these measurements, which are used to calculate the amount of electricity one utility system supplies to another, for instance.

Researchers in the Center for Materials Science:

- developed a technique for measuring the viscosity of liquids at extreme pressures. This is yielding data with important implications for the manufacture and use of the "superlubricants" that will be needed for new machine designs.

- made a comparative study of flame temperature measurements by conventional optical methods and novel Raman spectroscopic techniques. The results have demonstrated improved levels of accuracy and have defined the conditions needed for accurate and reproducible temperature measurements used in combustion research and flame inhibition studies.

- successfully obtained pressure measurements on a Bureau of Engraving and Printing press equipped by NBS with a new pressure sensing device made from piezoelectric polymers, an unusual class of materials with which NBS is experimenting in a number of new applications. This agency has not previously been able to make the sensitive measurements permitted by the NBS device and needed for quality control in the printing of currency.

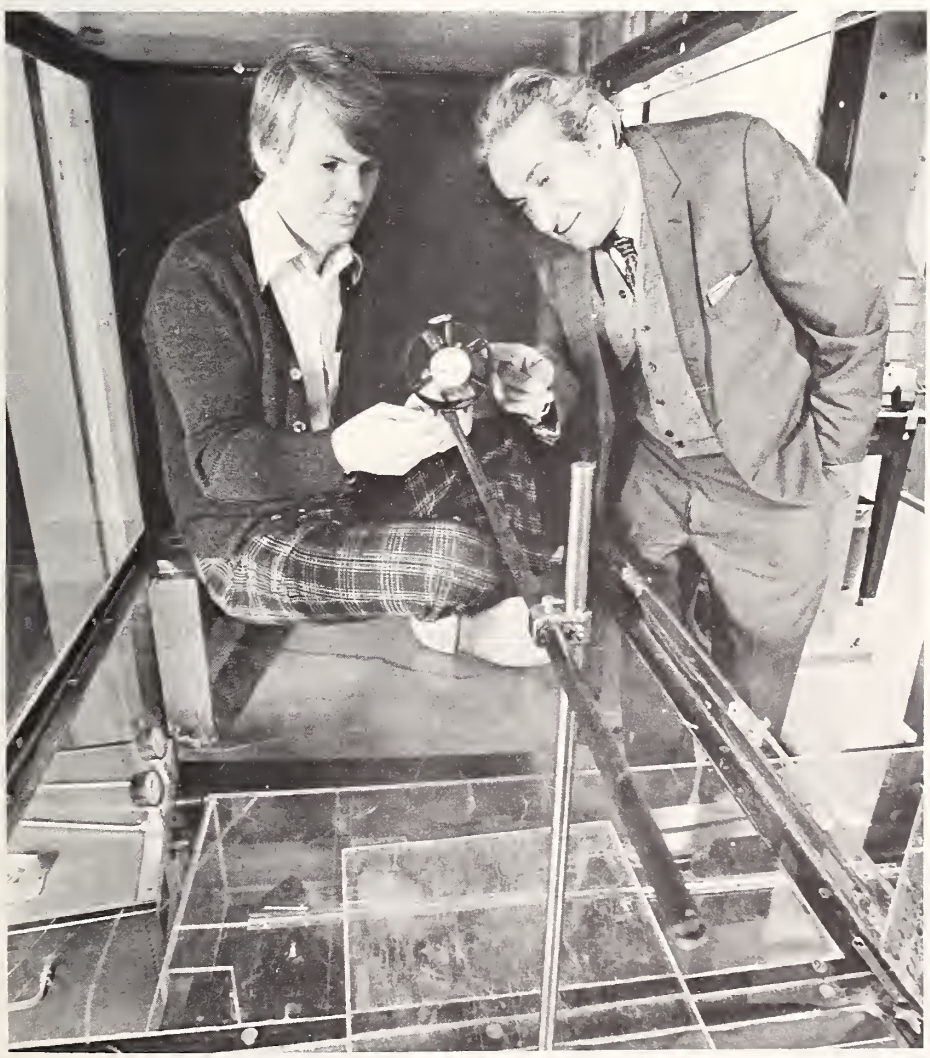
- developed a new instrument for use in nondestructive evaluation of materials using neutron beams. This "multi-detector high-resolution diffractometer for neutron diffraction-profile analysis" is the first of its kind in the United States.

Researchers in the Center for Analytical Chemistry:

- studied unusual characteristics of a meteorite which suggest that it is "primitive," that is, relatively unchanged since its formation. Primitive meteorites are of special interest to scientists since they provide one of the best clues to the early makeup of our solar system. NBS studied the meteorite in cooperation with scientists from the Smithsonian Institution. They were able to examine the material and assess its characteristics by using an extraordinarily sensitive ion microprobe.

- demonstrated a new technique for measuring the fluctuations in concentrations and the average concentration of individual chemicals in a turbulent gas flow. The improved accuracy in measurement afforded by this research, performed in conjunction with the NBS Center for Fire Research, is important to our understanding of flame and combustion processes and efforts to achieve more fuel-efficient, less polluting combustion.

- developed two Standard Reference Materials (SRM's) for wheat and rice flours. These SRM's will help assure the accuracy of measurements of important constituents in flour present only at very low concentration. Developed with partial support of the Food and Drug Administration, these measurement references will assist environmentalists, medical researchers, nutritionists, and other food scientists who are interested in the nutrients and contaminants contained in cereal foods—the source of one-fourth of the total caloric intake of the U.S. population.



The Center for Radiation Research:

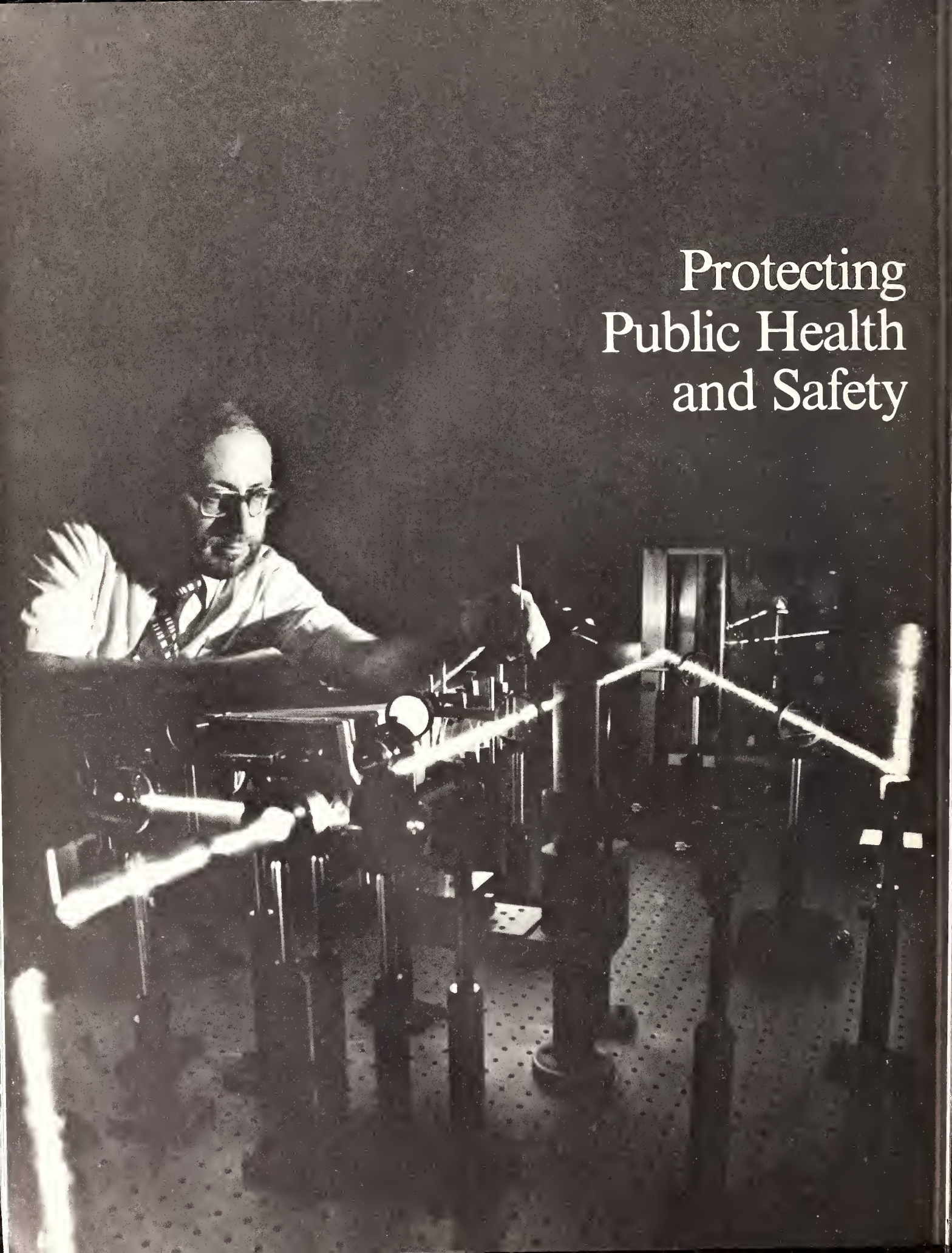
- completed a measurement of the radius of the carbon nucleus to an unprecedented accuracy, within 10 attometers (i.e., $\pm 10 \times 10^{-18}$ meters). This new value will become the benchmark against which other nuclei are measured and will be fundamental to measurement in nuclear physics.

- measured the continuous light output of a single electron orbiting in a magnetic field. This technique permits radiometry to be placed on an absolute physical basis (that is, in terms of orbit radius and magnetic field strength). Synchrotron light in the far ultraviolet wavelength region is being used at NBS for a variety of research projects in atomic, solid, and biological systems.

- developed a reliable, high current source of polarized electrons for studying the spin-dependent interactions of electrons with materials. The electrons are produced using the photoelectric effect in a semiconductor with circularly polarized light. Expected to be of great importance in areas of basic research such as surface science, this steady, reproducible electron source has already found application in significant research projects at NBS and other U.S. laboratories.

A unique low-velocity airflow facility has been designed and developed at NBS. Researchers Patrick Purtell (left) and Philip Klebanoff examine a vane anemometer that has been tested in the facility for the U.S. Bureau of Mines. The test results will help establish accurate safety standards for mine ventilation.

Protecting Public Health and Safety



NBS physicist Stephen Seltzer examines a jawbone with the new "Lixiscope," a portable x-ray device that he helped NASA to develop. The Lixiscope permits certain x-ray examinations of patients with reduced radiation exposures. It may also find important industrial uses for nondestructive evaluation.

Medical Aids and Research

The Bureau's expertise in the measurement and physical sciences is brought to bear directly and in a variety of ways on the protection of public health and safety. Research in these areas is one of the more diverse efforts at NBS, involving many centers in the National Measurement Laboratory and the National Engineering Laboratory. Typical of this work are recent achievements important in the medical and health fields.

"Getting the most out of x-rays" used in medical diagnosis and treatment was the general theme emerging from several studies in the Center for Radiation Research. In one project, center researchers demonstrated that physicians and radiologists should be able to extract more information from x-ray photographs (radiographs) of patients than they now are. Like typical photographic negatives, if x-radiographs are underexposed, they will appear too light to read and analyze. Consequently, doctors and radiologists use a higher x-ray exposure in order to achieve a sufficiently distinct radiograph.

Actually, the currently unusable light radiographs in many cases already contain the information needed by physicians. In order to use them, however, emerging "image processing" techniques have to be utilized. These methods allow doctors to get more information from the film than the eye can see, but they are used sparingly now because of the lengthy processing time required. Still, the fast-paced development of this technology suggests that image processing will be available for much wider use in several years.

NBS has helped to foster the use of ultrasound as a diagnostic tool in the medical community. This interferometer system and the SonoChromoscope described on page 29 were developed by Melvin Linzer and his colleagues and can be used to examine tissue samples.

NBS researchers analyzed the makeup of x-radiographs and the levels of x-ray exposure at which important body structures could still be revealed if image processing techniques were to supplement the usual development methods. Bureau scientists were able to relate mathematically the image content and the patient's exposure, giving estimates of the minimum exposure required for detecting particular images sought. For diagnostic examinations regularly administered to large segments of the public, such as chest x-rays, the NBS researchers found that adequate information could be provided with patient exposures at less than 10 percent of current levels.

This same concept, getting more information from lower levels of x-ray exposure, was evident in studies leading to the joint development of an extraordinary new diagnostic tool by a researcher in the NBS Center for Radiation Research working with a team at the National Aeronautics and Space Administration's Goddard Space Flight Center. By coupling a variety of components not previously used in x-ray diagnosis and utilizing advice and equipment supplied by other Federal agencies, the researchers constructed the first small, hand-held x-ray fluoroscopic unit.

Called the "Lixiscope" (for low-intensity x-ray imaging scope), the new tool is about the size of a camera and weighs only a few kilograms, compared to the heavy, immobile units in hospitals. Although the instrument is not as powerful as conventional x-ray machines—and therefore is most useful for examining an individual's extremities rather than thicker body portions—its portability and battery-powered operation have a variety of advantages. For example, the Lixiscope may be particularly useful in emergency situations. One of its major attributes is the possibility of making certain radiographic examinations at dramatically reduced exposures compared to conventional x-ray machines.

The Lixiscope uses a low-level x-ray emitting material (a radioactive isotope) which, by itself, produces only a poor photographic image of the area being examined. However, by adding a night vision scope—widely used in military operations to "see" at night by intensifying very low light levels—even those poor images are amplified and become visible to the physician.

The device has received preliminary testing in a range of dental and medical applications. Several manufacturers

Building Safety

Many of the projects undertaken by the Center for Building Technology are intended to promote safety during the construction process and after buildings are completed. Some of the research performed by this center covers building materials and construction methods, as well as the safety of building occupants. Recently this center:

- brought together building community representatives, standards setting bodies, and Federal agencies to discuss plans to assess and implement tentative building design provisions for mitigating the impact of earthquake activity on buildings and their occupants. The tentative provisions were developed for NBS and the National Science Foundation by the Applied Technology Council with input by experts from NBS, other laboratories, and professional practice. NBS was assigned responsibility for the development of seismic design and construction provisions for buildings by the Federal Earthquake Hazards Reduction Program submitted by the President to Congress in July 1978. Also, as part of a team of U.S. experts, a Bureau researcher with strong expertise in this field was dispatched in June 1978 to inspect and

analyze the damage caused by an earthquake off the Japanese coast.

- sent researchers to the site of the April 1978 cooling tower collapse at Willow Island, West Virginia, which killed 51 construction workers. NBS carried out an in-depth engineering investigation of the collapse at the request of the Occupational Safety and Health Administration (OSHA) and examined both scaffolding design and the strength of concrete used in the structure. Field and laboratory investigations were conducted.

The development of a technical basis for codes that govern building rehabilitation and research dealing with construction materials and practices are two examples of the wide variety of building-related safety work undertaken at NBS.

- studied for OSHA the technical provisions in Federal regulations which govern construction-related excavations, trenching, and shoring. In addition, Bureau researchers began work on a technique for determining the strength of concrete in existing structures.

- produced a manual for home safety design that presents information on home accidents and ways to reduce their frequency and severity. It is intended to be used in the design or rehabilitation of dwellings. The document is aimed at architects, but the information is expected to be useful to homebuilders, product designers, and homeowners.

- published an analysis of the National Cancer Institute's emergency isolation facility. Based on studies performed in conjunction with several Federal agencies and other organizations, the analysis of this building served as a case study to develop a methodology for evaluating buildings once they are occupied. Safety was an important factor in the building's design, which was analyzed to see how well it met occupant needs.

- completed a study of building rehabilitation, including the development and enforcement of building regulations—the major vehicle for ensuring minimum requirements for public health and safety in buildings. This study addressed technical needs relating to rehabilitation and adjustments needed in the regulatory process. NBS has been supporting the efforts of several model code and building regulatory groups to develop a model code for building rehabilitations.

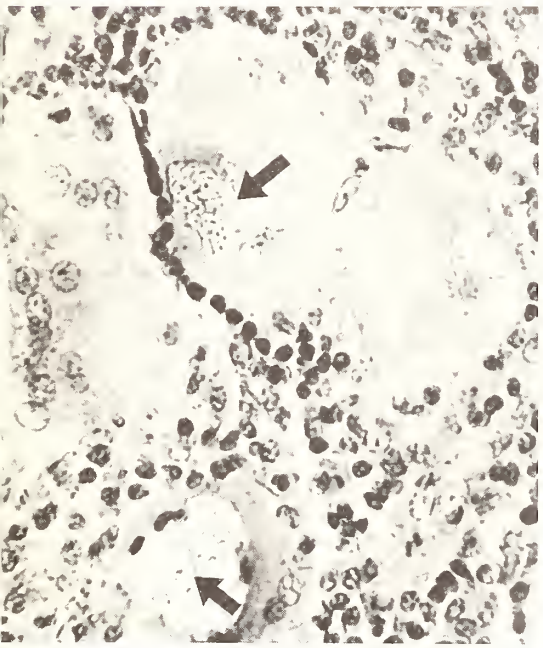
- issued a report describing methods to simplify and improve the selection of criteria for reinforced concrete designs so that safety margins are set on a firm engineering and statistical basis.

have applied for and been granted licenses to produce the government-patented Lixiscope, which may also find important industrial uses for the nondestructive analysis of materials and equipment components.

The Center for Radiation Research registered a number of other noteworthy achievements in fiscal year 1978 with implications and potential in the medical field. These include several projects that could aid in cancer therapy. NBS scientists developed a theoretical method for predicting certain characteristics of electron beams that will help calculate radiation dosage. Since there is a delicate threshold at which radiation will destroy cancerous cells but permit healthy cells to live, it is crucial that therapists know precisely what dosage is received by the patient. The NBS predictive method could provide a more accurate way to make that determination.

NBS also established exposure standards for iridium-192, a radionuclide often used in cancer therapy. To assure that treatment centers using this material are certain of their measurements, NBS has set up calibration services for their use.

In another area of medical research, scientists in the NBS Center for Analytical Chemistry have pioneered the special use of a technique which could well become an invaluable tool in biomedicine and pathology. The technique utilizes a laser-excited micro-Raman spectrometer not previously used to test biological tissues and cells. The Raman microprobe, as it is called, is likely to be of special significance in detecting occupational or environmental diseases for which existing techniques are inadequate.



The laser-excited Raman microprobe developed by Greg Rosasco (foreground) and Edgar Etz has been used successfully to identify molecular constituents in many materials including microscopic air particulates and geological fluid inclusions as well as to characterize organic molecular species in biological tissues and cells. For example, the previously unidentified foreign particles in the lymph node tissue at left were shown to be silicone rubber microparticles.

When medical researchers and doctors find or suspect that foreign material has been introduced into body tissue, they need to know the distribution and identity of the particles or dissolved material. Conventional microanalytical tools cannot reveal as much information about the material as medical researchers would like. Having heard about NBS work using the Raman microprobe, an instrument used to characterize microscopic samples, a pathologist at the University of California, San Diego, approached the Bureau about its possible application to the analysis of living tissue. NBS agreed to try out the technique. The pathologist supplied NBS with thin sections of lymph node believed to contain foreign particles of silicone polymer. It was suspected that the particles were related to a silicone finger joint prosthesis implanted in the patient.

Research confirmed this suspicion and supported other previously undocumented medical indications that microparticles can migrate from an intact and normally-functioning implant to a distant lymph node. Many possibilities have been opened up by the NBS application of the microprobe. The technique should make it possible to obtain much needed information about the identity, precise distribution, and relative abundance of certain constituents within tissues and cells and thus contribute significantly toward understanding many essential tissue and cellular processes. The experiment also raises the possibility that the technique can be used to detect, pinpoint, and characterize a number of environmental and occupation-related contaminants within individuals.

Scientists in the Center for Materials Science also made progress last year in the areas of synthetic implants and dental research. Companies fabricating plastic synthetic implants—used to replace damaged or diseased parts of the body, such as hip, knee, and ankle joints—need reliable means for specifying and testing the plastics in order to guarantee the long-term safety and durability of this product.

Fire Research

Fires take more than 7,500 lives, cause 310,000 injuries, and result in billions of dollars of property damage in this country each year. As the Federal government's prime fire research laboratory, the NBS Center for Fire Research seeks to reduce that toll by improving our knowledge of the way fire works and what we can do to prevent, forestall, or minimize its destructive effects. In fiscal year 1978, this center:

- developed a new device that can test any installed smoke detector to see whether it is sufficiently sensitive and in good working order. The NBS instrument is intended for use by fire departments and maintenance personnel in periodic tests and has been used successfully in several demonstrations.
- examined in laboratory and full-scale tests the role of various mobile home interior finish materials in fires as part of a program sponsored by the Department of Housing and Urban Development.
- presented several new test methods for assessing the flammability of thermal insulation and saw them adopted for Federal insulation procurement specifications. (See page 34.)
- prepared a system for grading health care facilities in terms of fire safety. The system offers flexibility to the designers of new facilities and to those remodeling existing health care buildings. It can be used to determine how combinations of fire safety equipment and building construction features may provide a level of safety equivalent to that specified in the widely accepted National Fire Protection Association Code. The Center for Building Technology and the Center for Applied Mathematics also worked on this joint project. Several Federal agencies have asked NBS to prepare a similar evaluation system for application to housing for the developmentally disabled and to multi-family residences.
- sponsored the preparation of audiovisual training aids for health care personnel in the basics of smoke spread and control and fire "flashover," the point at which a small, nonthreatening fire suddenly becomes a violent force which can envelop an entire room in flames. The film and slide presentations are based on NBS research for the Department of Health, Education, and Welfare.
- saw an NBS test for judging the flammability of corridor flooring systems adopted by both the National Fire Protection Association and the American Society for Testing and Materials.
- developed a model for routing people from buildings under emergency situations. This work was performed with the assistance of the Center for Building Technology and the Center for Applied Mathematics. Designed to minimize evacuation time and bottlenecks, the model will provide valuable information to architects, municipal building code officials, and safety officers.

NBS is helping to develop a test method for assessing the potential toxicity of combustion products generated when household materials burn. Left to right, chemist Susan Womble, physiologist Dolores Malek, and biologist Barbara Levin measure amounts of toxic materials in the blood of research animals and in their immediate environment.

Consumer Product Safety

As more attention is focused on the potential hazards of certain consumer products and the costs and benefits of regulating their manufacture to ensure consumer safety, there is an expanding need for technical expertise in developing useful and economically efficient testing and product standards. Recent activities in the NBS Center for Consumer Product Technology are aimed at filling this need and include:

- testing of a device claimed to be effective in shutting off unvented gas-fueled space heaters so that carbon monoxide levels in a room will not reach dangerous levels. NBS tests showed that the apparatus worked well, leading the Consumer Product Safety Commission (CPSC) to reconsider a total ban it had proposed on these space heaters.

- completion of a testing device, test procedure, and mathematical model to gauge the likelihood of eye injury from children's toys which propel objects. When the prototype device was used in laboratory tests of projectiles, the results correlated well with the model. Work is continuing in this area for CPSC with Bureau researchers testing human eyeballs donated to eye banks for research purposes.

- continued development of predictive methods which will be used in establishing standards for protective headgear, such as football helmets.

- technical assistance by the NBS Law Enforcement Standards Laboratory (LESL) on tests of body armor worn by police officers. Based on a LESL-developed voluntary standard, tests conducted by the International Association of Chiefs of Police and the Law Enforcement Assistance Administration determined that nearly half of the commercially-available vests tested did not meet performance levels claimed by manufacturers.

- completion of guidelines on window and door security by LESL. These guides are intended to acquaint the general public, architects, and building code officials with the window and door security standards developed by LESL for the Law Enforcement Assistance Administration.

- assistance to CPSC in evaluating safety tests for miniature Christmas tree lights. NBS proposed several of its own tests in addition to those previously recommended to CPSC by the National Consumers League, a group which had drafted test standards for the Commission. CPSC adopted the proposed NBS changes as part of its possible standard for the lights. Underwriters Laboratories, a nationally recognized testing firm, independently adopted the NBS methods for use in its testing.

The Bureau's Law Enforcement Standards Laboratory develops standards and guidelines for law enforcement and criminal justice equipment. Ralph Gorden is shown with laboratory arrangement used to test performance of body armor worn by police officers.

As part of a cooperative program with the American Dental Association, NBS has made and begun to test dental appliances cast from a titanium alloy that may be as good as gold. Below, Richard Waterstrat, a Research Associate at NBS, examines the structure of the casting, which is shown in a close-up being checked against a master casting of a patient's mouth structure.

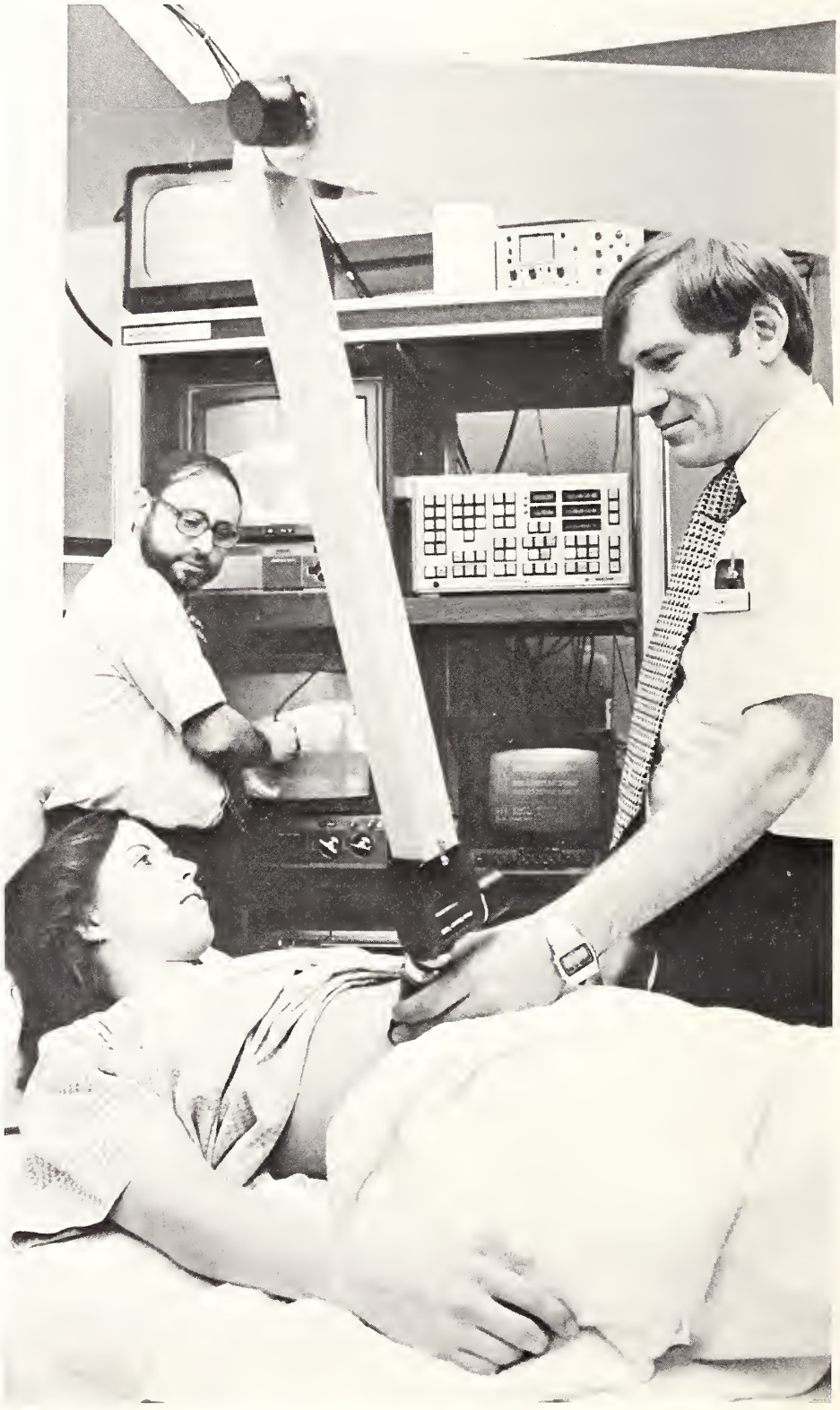
Particularly important to such applications is resistance to wear, a characteristic dependent in part on the molecular weight of the plastic. In collaboration with a guest worker from the Food and Drug Administration (FDA), NBS researchers in the Center for Materials Science have shown that a commonly used method for measuring the plastic's molecular weight is unreliable. They are currently working on a more accurate measurement method.

In cooperation with the American Dental Association Health Foundation through its long-standing Research Associate Program at NBS, the dental materials and products group within the Center for Materials Science completed several major projects. With the rising cost of gold, the need for alternative dental alloys has become more critical. Titanium alloys, used extensively in the aerospace industry and lately for artificial hip joints, have been considered for dental applications because of their resistance to corrosion and compatibility with body tissues. Recent efforts in the dental program demonstrated for the first time that a titanium alloy could be used in dental castings by employing conventional dental laboratory equipment. This leads the way for use of this less expensive alloy to supplement or replace gold as a basic dental material.

As part of the same program, researchers developed a new fabrication procedure for dental porcelain that promises better quality control and a reduction in space and labor requirements. They also demonstrated a method for significantly improving the storage stability of certain dental composites used in fillings and developed an inexpensive analytical technique to measure the low levels of fluoride concentration encountered in dental applications.

NBS has developed and produced more than 70 Standard Reference Materials (SRM's) for medical measurement applications. SRM's are well characterized materials or measuring devices which have one or more physical or chemical properties certified

The SonoChromoscope is a unique medical diagnostic tool which projects sonic pulses into living tissue and analyzes the response. The signals are processed into pictures with the aid of a computer. Thomas Shawker (foreground) of NIH is testing the device, aided by NBS developer Melvin Linzer.

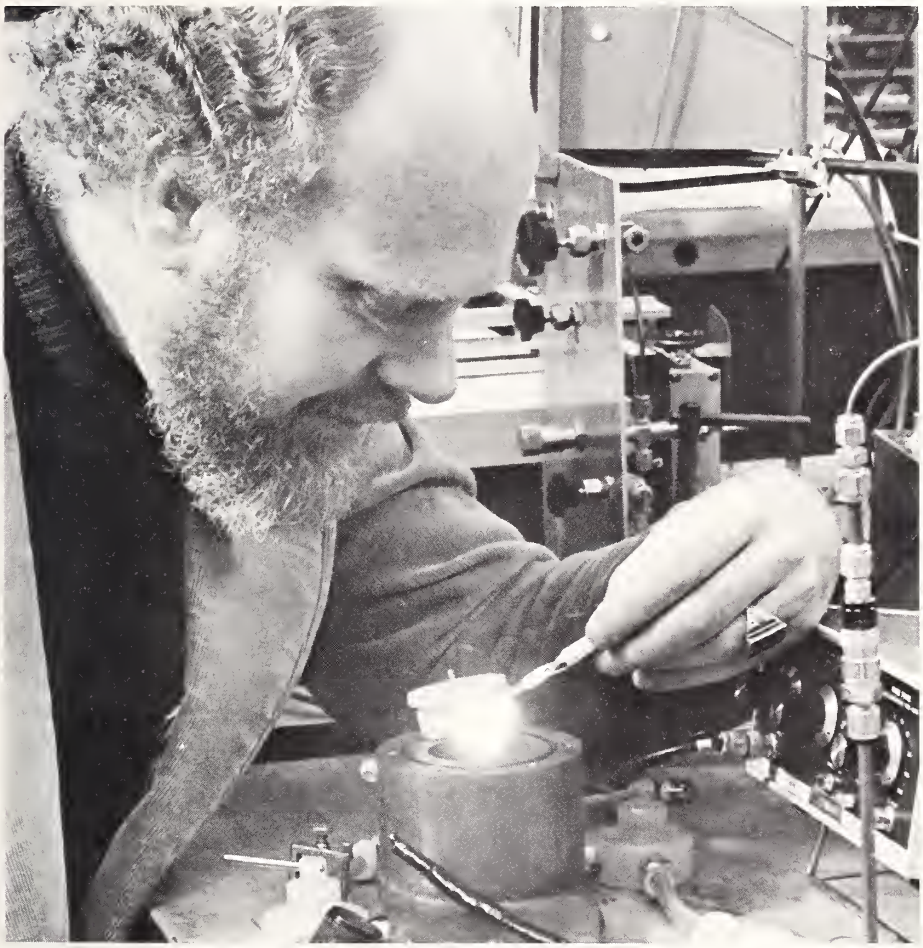


by NBS. They come in many different forms, from fine crystals or powders to sealed vials and thermometers. SRM's are used widely for calibrating or testing all kinds of measuring instruments and are an important Bureau service to many users (see page 67). The Bureau's SRM's are especially needed in the clinical chemistry area, where 4 billion measurements are made annually and where accurate measurements are essential to aid physicians in diagnosing disease. Working through the NBS Office of Standard Reference Materials, the Center for Analytical Chemistry has completed several projects of immediate usefulness in clinical analysis.

A newly developed SRM will assist physicians in monitoring anti-epilepsy drugs in the serum of patients under therapy. Serum is the clear substance remaining after red blood cells, fibrinogen, and various other components of blood samples are separated out. In the case of epilepsy, knowledge of the exact concentrations of anti-epilepsy drugs in the patient's serum is very important, especially in the treatment of patients whose disease is difficult to control. Yet, comparisons among laboratories have documented disturbingly large variations in measurement accuracy. The new NBS SRM consists of freeze-dried human serum containing four anti-epilepsy drugs at various accurately determined concentrations. Another new SRM, for use in determining iron in serum, was issued by NBS and will be relied upon in the diagnosis of hepatitis, obstructive jaundice, and various anemias.

During FY 1978, a new definitive method was developed by NBS for the accurate analysis of cholesterol in serum. Based on a special technique (isotope dilution mass spectroscopy),

NBS is one of a handful of labs in the United States studying the basic theory, properties, and applications of piezoelectric polymers, which have a number of medical uses. Here, physicist Martin Broadhurst places polymer transducer in a cell for measuring piezoelectric constants.



this method will be used with previously developed NBS definitive methods for other serum constituents in the certification of a human serum SRM. This SRM will be useful in the accurate diagnosis, monitoring, and treatment of a range of medical conditions in patients. Like all clinical analysis SRM's, it will be particularly important to patients who move from one part of the country to another or to those who travel and need assurances that the laboratory serum measurements are correct and based upon comparable equipment and procedures.

The Bureau is working in other measurement-related health areas. Techniques using ultrasonic waves outside the hearing range of the human ear have been introduced in medical and industrial applications over the past several years and are providing the medical community with new and exciting diagnostic and therapeutic tools. NBS has helped to foster use of this technology. A new Bureau device, known as the SonoChromoscope was developed by a scientist in the Center for Materials Science. It is being evaluated by the National Institutes of Health (NIH) and is receiving close attention as an aid in detecting tumors and fetal defects. It may also prove to be a safer way to screen for breast cancer than the currently used method of x-ray mammography.

Other Safety Research

Many other projects at NBS designed to protect public health and safety were completed or reached significant milestones during the fiscal year. For example:

- Scientists in the Center for Thermodynamics and Molecular Science calibrated and characterized pressure transducers that will help aircraft pilots keep better track of their altitudes.
- A new instrument which uses low-power microwave radar to monitor coal seam thickness in mines was developed in the Center for Electronics and Electrical Engineering. Use of the instrument is expected to help improve mine safety and coal mining productivity. Also, the Center for Applied Mathematics devised a statistical plan for testing coal mine dust samplers in collaboration with the Bureau of Mines and the Mine Safety and Health Administration.
- Test methodologies and data have been developed to assess the mechanical durability of plastic shipping containers used for hazardous materials transportation. This work was conducted in the Center for Materials Science.
- An extensive investigation of an over-the-highway steel pressure vessel that ruptured while being filled with natural gas was conducted by the Center for Materials Science for the Department of Transportation. The NBS investigation of the accident, which killed two people, has pointed to the critical need for developing a data base to evaluate the susceptibility of pressure vessel steels to hydrogen enbrittlement caused by harmful chemicals.

Ultrasound offers safety, cost, and application advantages over conventional equipment for some purposes. But, like x-ray techniques, ultrasonic methods require that the dosage be known accurately if its users are to receive correct information about the area examined. Furthermore, studies of possible biological effects and the development of safety standards for medical uses of ultrasound rely on accurate measurements.

Researchers in the Center for Materials Science have constructed a prototype transducer which gives a more accurate measurement of ultrasound dose and will help to calibrate other transducers—critical components of ultrasound devices which send out sonic radiation and receive the return sonic signal which bounces off and helps characterize the targeted body area. The new transducer is made of piezoelectric polymers, materials which can deliver an electrical charge that is related to the pressure placed on the polymer. NBS is one of a handful of laboratories in the United States studying the basic theory, materials properties, and applications of piezoelectric polymers. A pioneer in applying these materials, the Bureau has developed a number of piezoelectric devices useful to the medical community.

NBS work on the polymer transducer prompted FDA to send a guest worker to the Bureau to investigate the design and construction of the device. The report: the polymer transducer offers a number of advantages over its currently used crystal or ceramic counterparts and facilitates more accurate measurement of ultrasound dose. While the total and average dose delivered by an ultrasonic beam may be considered

Nuclear Safeguards

A number of notable achievements in the area of nuclear safeguards were registered last year as part of a continuing, interdisciplinary program involving several NBS centers. Coordinated by the Office of Measurements for Nuclear Safeguards, NBS work in this area is supported by the U.S. Nuclear Regulatory Commission and the Departments of Energy and State. This research aims to improve the quality of nuclear fuel measurements, thus providing sensitive and timely methods for detecting and determining diversion of nuclear materials from government and industrial facilities in the United States and abroad. Accomplishments in FY 1978 include:

- development of a method for calibrating the volume of storage tanks for nuclear materials that is 10 to 100 times more accurate than existing methods. This work by the Center for Mechanical Engineering and Process Technology is of the utmost importance since accurate knowledge of the volume of these tanks is essential for the determination of the mass of stored nuclear material and for subsequent accounting of this material as it passes through the processing facility. The Center for Applied Mathematics contributed to the improved volume calibration by providing a new methodology for handling the large amounts of data involved in the calibrations.

- substantial improvement in the determination of the half-life of plutonium 239 in the Center for Radiation Research as part of a concentrated national effort in this area.

- demonstration of the feasibility of a technique newly developed by the NBS Center for Radiation Research for identifying plutonium and uranium content in nuclear fuel materials. Based on resonance neutron radiography, this technique can reveal differences not only among elements but also among isotopes, providing a more accurate indication of the nuclear material. In a related project, Center for Materials Science researchers, in conjunction with the Los Alamos Scientific Laboratory, made progress in the development of a resonance neutron tomography technique that also could provide greater accuracy in the same difficult measurement area.

- development of an improved uranium assay Standard Reference Material (SRM). This is one of a series of SRM's being developed by the Center for Analytical Chemistry that will bring about an improvement in the calibration of instruments used to measure nuclear materials.

- completion of a study to determine whether infrared thermography techniques would be useful for measuring plutonium accumulating in pipes and other segments of the nuclear fuel cycle. Thermography, which measures temperature differentials due to heat liberated from plutonium, has been considered a promising measurement method. However, this research in the Center for Absolute Physical Quantities indicated that the technique has major limitations and is not likely to be useful for quantitative plutonium measurement applications.

- development of methods to evaluate the performance of pressure transducers used to measure the volume of nuclear materials in fuel tanks. This work was performed in the Center for Thermodynamics and Molecular Science.

- publication and field demonstration of a diversion path analysis handbook written by scientists in the Center for Radiation Research for operators of government-owned nuclear facilities.

NBS uses its nuclear research reactor for a variety of experimental work, including the analysis of environmental and biological materials. Radiochemist Tom Gills inserts a sample into the reactor.

Using the NBS nuclear research reactor, scientists from NBS and a number of other Federal agencies have helped solve some of today's most urgent problems, including public health protection. The reactor has recently been put to work in analyzing more than 120 foods for toxic and harmful contaminants. This continuing project for FDA—which has several of its staffers stationed at the NBS reactor—uses a very sensitive neutron activation analysis method. The project has established baseline levels of contaminants in foods so that over a period of years it will be possible to monitor whether our food is becoming more contaminated.

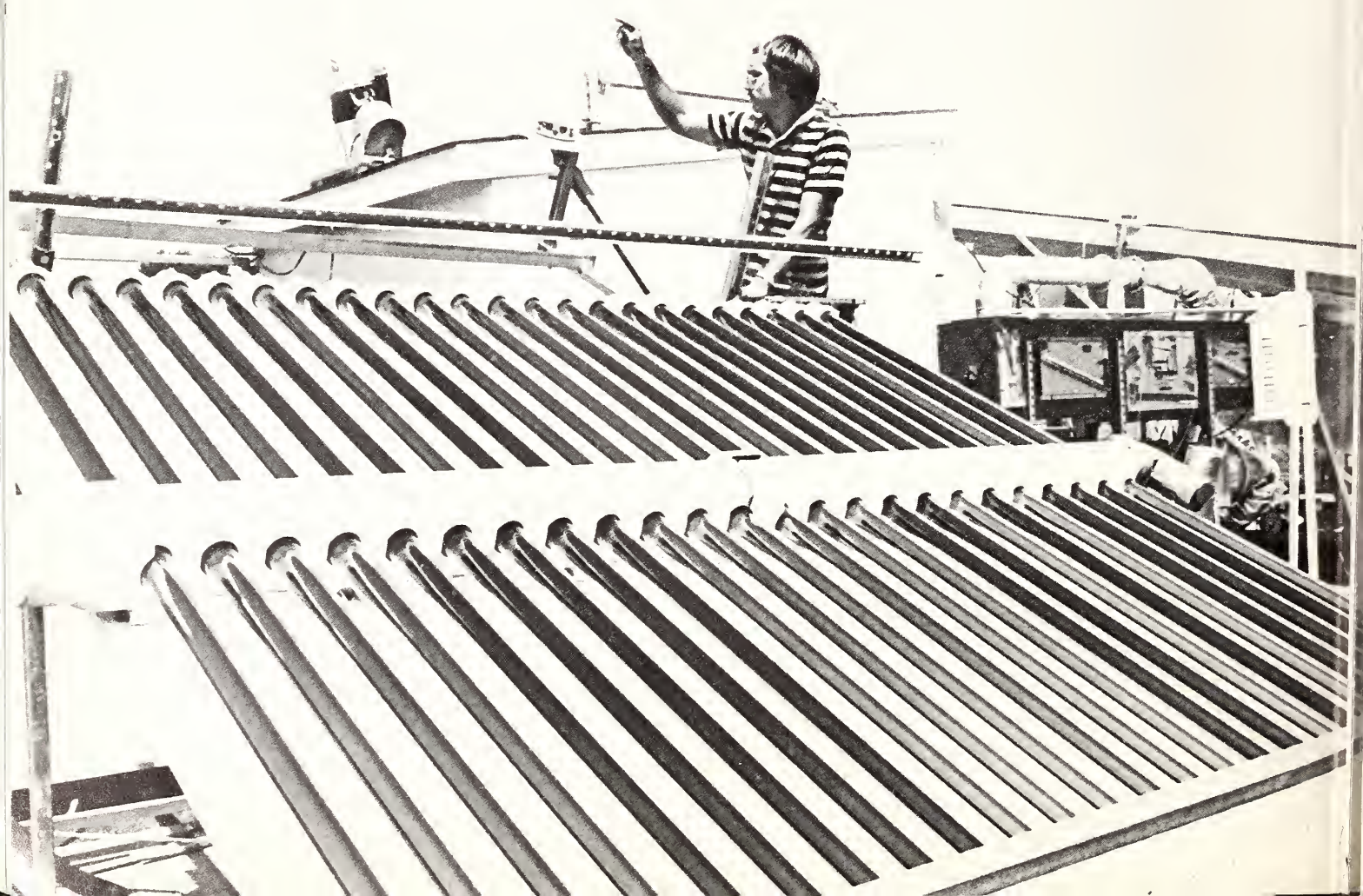
The reactor was also used by NBS scientists in a collaborative effort with the NIH Laboratory of Molecular Biology in a study of enzyme structures. These researchers developed a method to determine the structure of very large, complex macromolecules, such as those in body enzymes and proteins. They then used this method and a high intensity neutron beam to study ribonuclease, a digestive enzyme. Scientists conducting this research were particularly interested in structural details related to hydrogen bonds in the protein chains—information which is critical to an understanding of all enzymes but very difficult to obtain with conventional techniques. This NBS effort is the only one of its kind in this country and is one of just three such studies being carried out in the world.

It is a prime example of how unique NBS experimental facilities and technical talents are put to work in advancing medical research and contributing to the improvement of public health.

safe, there has been no way to tell whether some small part of the beam focused on a limited area of the body might be harmful. The NBS transducer can measure the smaller segments of the beam and provide the needed information. Because of this special capability, FDA has been using the Bureau's innovation to better characterize ultrasonic doses.

Meanwhile, the Center for Mechanical Engineering and Process Technology initiated an international comparison of measurement methods used to determine the power output of conventional ultrasonic transducers. These powerful measurement methods are used to help establish safe, effective levels of ultrasound for medical applications and for establishing performance characteristics for transducers used in ultrasonic nondestructive evaluation of materials. Four specially designed NBS devices have served as the basis for the comparison.

Using Energy Resources Efficiently



Over the past several years, the Department of Energy (DOE), other government agencies, Congress, and private industry have been looking to NBS more frequently for the Bureau's energy-related measurement expertise. NBS has taken advantage of its broad, multidisciplinary capabilities in responding to the dual energy technology challenges of increased conversion efficiency and greater end-use conservation. Guided by the Bureau's Office of Energy Programs, important energy-related tasks are being carried out in every major unit of the National Engineering Laboratory. Several units of the National Measurement Laboratory also have energy-related activities underway.

Conserving Energy in Buildings and Consumer Products

When the National Energy Conservation Policy Act (NEA) was signed into law in November 1978, it authorized a full slate of programs for energy conservation in buildings, including tax credits for homeowners who install energy conserving devices in their homes, requirements that utilities offer to inspect and analyze the energy efficiency of customers' dwellings, and minimum efficiency standards for appliances.

The law also calls for a series of guidelines and standards to be adopted by the Federal government in carrying out the conservation provisions. Even before the statute was passed, NBS had been working with DOE on related research programs. The Bureau is formally mentioned in the energy law a number of times and also has been selected by DOE to provide needed performance criteria and measurement technology where there is no specific Congressional assignment made to NBS or to the Department of Commerce. With its historic role as a focal point for building research within the Federal government and its particular expertise in buildings and energy conservation, the NBS Center for Building Technology has contributed to many of the NEA tasks related specifically to energy conservation in buildings. The Center for Fire Research and the Center for Consumer Product Technology also have been involved. The Bureau does not actually set any of the standards called for in the statute, because NBS is not a regulatory agency. Rather, NBS performs the technical energy conservation research needed to help voluntary standards-setting groups or government agencies make their decisions about standards.

One major portion of the NEA requires utilities to inform their residential customers about energy conservation measures they should consider and to offer to inspect dwellings and analyze their energy efficiency. As part of this NEA utility program, DOE is authorized to develop standards necessary for the general safety and effectiveness of any residential energy conservation measure, with installation standards receiving special mention. Bureau engineers played a significant part in providing DOE with a technically-sound basis for deciding on those standards for energy conserving retrofit measures, including insulation, replacement oil burners, and storm windows. These standards may well be applied to other conservation programs included in the law. Also at the request of DOE, the Center for Building Technology developed a computer program that could be used to determine the most appropriate measures for various classes of buildings in different climates.

The NEA also directs the establishment of energy conservation targets for Federal buildings and authorizes a massive energy analysis and retrofit program. NBS has been involved in developing those targets. The law further mandates the use of "life-cycle cost analysis" on all Federally-owned buildings, covering both existing and proposed new structures. Life-cycle cost analysis is a method for evaluating the economic feasibility of building design and construction alternatives, taking into consideration all relevant lifetime costs and benefits. In terms of energy conservation projects in buildings, this technique offers a way to evaluate the net effect over time of reducing fuel costs by purchasing, installing, maintaining, operating, repairing, and replacing energy-conserving features. Although the technique is becoming more commonplace, there has been a lack of uniformity and consistency in its use.

Working to implement a Presidential Executive Order regarding Federal energy conservation programs and life-cycle cost analysis, economists in the Center for Building Technology devised and published an approach that could be used widely, not only by Federal building managers, but by other

The performance of an evacuated tube solar collector is monitored by NBS engineer John Jenkins. Solar energy research at NBS has led to some of the first voluntary standards for solar collectors and storage tanks. Standards are a first step in boosting confidence in this maturing industry.

Technician Tom Prather prepares a sample of insulation for testing in the NBS Attic Flooring Radiant Panel Test device. Based upon previous Bureau research in carpet flammability, this NBS-developed test method provides one measure of the relative flammability of various insulation materials.

building owners, designers, and operators as well. This NBS analytical technique is being used to meet similar life-cycle cost requirements included in the NEA.

An extension and expansion of a grant program to assist low-income families in making their homes more energy efficient is among the many NEA conservation provisions which do not single out NBS to perform a special task. However, this program will be drawing upon the technical information generated by the Bureau from its previous and current technical research or programs established by other legislation. NBS has helped DOE select the criteria for materials and products used in that grant program. Also, at the request of the Community Services Administration, Bureau engineers last year assisted that agency in training personnel for a similar program in low-income housing energy conservation.

Minimum energy efficiency standards for major household appliances to be set by DOE under the energy law will be based upon research and testing procedures undertaken by the Center for Consumer Product Technology and the Center for Building Technology. Evolving from an earlier Department of Commerce program, and as part of its assignment under 1975 and 1976 Federal energy conservation laws establishing voluntary and mandatory appliance labeling and efficiency programs, these centers have now developed methods for testing more than a dozen categories of appliances for energy efficiency. The appliances range from room air conditioners and water heaters to kitchen ovens and dishwashers. Particularly significant has been the development of testing procedures for certain appliances based on seasonal or "part-load" performance. This method permits a more realistic estimate of the annual cost of using the appliance by taking into account the energy performance effects of constant on-off cycling.

NBS studies involving energy conservation in buildings are also designed to meet the goals of other legislation or to satisfy special needs of government agencies or the private sector.

The testing of insulation flammability carried out in the Center for Fire Research illustrates this work. Using the Bureau's extensive fire test facilities and constructing special test apparatus, engineers in the center were able to gather information about the flammability of a variety of thermal insulation products and develop two new flammability tests.

For one of the recommended test methods, the attic floor radiant panel test, researchers used a modification of a laboratory device which had been utilized to judge the flammability of carpeting in prior Bureau research. Soon after the NBS methods were recommended, the General Services Administration adopted them in specifications applying to Federal insulation purchases. They were also published by the Consumer Product Safety Commission for public comment and possible inclusion in the agency's mandatory cellulosic insulation standard ordered by Congress in 1978.

In this same safety area, researchers in the Center for Building Technology tested the effect of sandwiching electrical wiring between thick layers of insulation. Preliminary results indicated that the wires could reach temperatures higher than currently accepted code levels. Follow-up research sponsored by DOE is being conducted to learn more about this possible hazard.

In addition to this work, listed below are several significant energy conservation achievements from the Bureau's Center for Building Technology.

- Working with DOE through the NBS Office of Energy Programs, a 5-year national program plan for research on insulation and the building envelope was drafted. The plan will help direct and coordinate Federal and private sector efforts to answer the most important research questions in this area. Special emphasis has been placed on

The Bureau carries out a variety of multidisciplinary, energy conservation-related research for other Federal agencies, particularly in the area of insulation. Here, mechanical engineer Douglas Burch inspects some cellulosic insulation in the attic of the Bureau's test facility.

current and future NBS and DOE research to assess how entire building sections—like walls, floors, and roofs—perform as a system to retard the flow of heat into and out of buildings. The plan also addresses problems of insulation performance and safety.

- Having extensively instrumented three test homes in Houston, Texas, Bureau engineers concluded that powered attic ventilators may not be as effective in cutting air-conditioning costs as has sometimes been suggested. At the same time, the research provided data to quantify the obvious energy savings that can be achieved by ventilating a residence with a whole-house fan instead of cooling it with an air conditioner.

- The energy saved by extensively retrofitting a poorly insulated wood frame house on the main NBS campus in Gaithersburg, Maryland, was documented. A combination of storm windows and insulation cut the energy consumption of this particular house by 58.5 percent. While some houses can expect more and some less energy savings, this NBS project definitively showed that commonly advocated energy conservation measures can indeed reduce energy requirements and save on heating bills.

- A new "guarded hot plate" was built which will enable NBS to provide manufacturers and testing laboratories with transfer standards and Standard Reference Materials for calibrating their own equipment to test the thermal resistance of thicker layers of insulation.

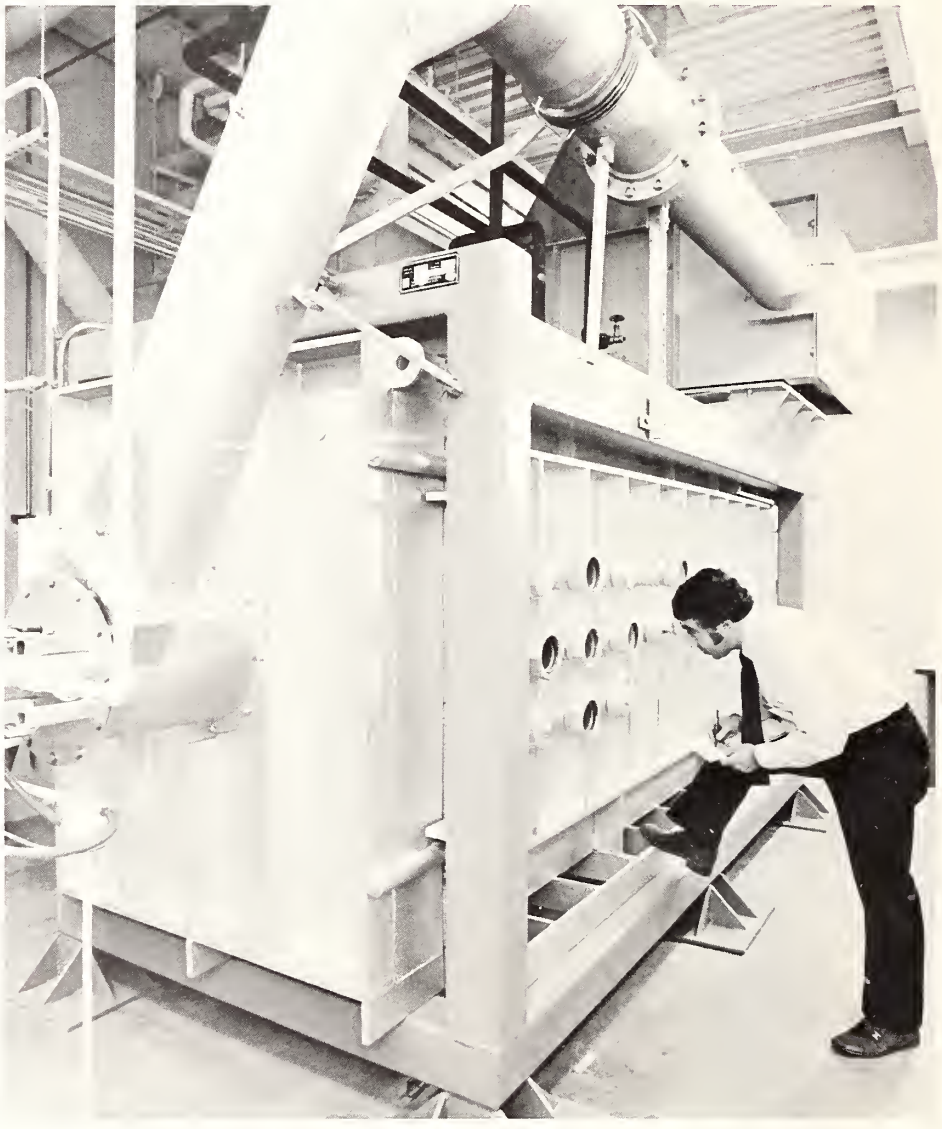
- The 11-story administration building at NBS headquarters was instrumented as part of a DOE-sponsored project to determine how much the flow of outside air in a normally functioning office building may be reduced without affecting the comfort of occupants. The data that are gathered will be useful in several projects concerned with the relationship between ventilation and energy conservation.

Boosting Solar Energy Use

The many NEA incentive and demonstration programs for solar energy applications in home heating, hot water, and cooling will rely heavily on earlier Bureau research and standards work conducted under the Solar Heating and Cooling Demonstration Act of 1974 and other programs. For example, researchers in the Center for Building Technology's Solar Technology Program recently revised the interim performance criteria for residential solar heating and cooling systems. These guidelines are used in the multi-year Federal demonstration program which has led to assistance for several thousand dwelling units incorporating solar systems.

Bureau engineers also verified a standard for judging the performance of devices which store up a solar energy system's heat. This standard had been drafted originally by NBS and later was adopted by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). Following a Bureau tradition of developing draft documents that can be used by voluntary standards organizations and subjected to public review through established consensus procedures, NBS engineers last year

Researcher Hratch Semerjian peers into the Bureau's new model industrial furnace that is being used to study the combustion process and the transfer of heat which takes place when fuels are burned in furnaces and boilers.



also helped ASHRAE draft a voluntary standard for testing entire solar hot water heating systems.

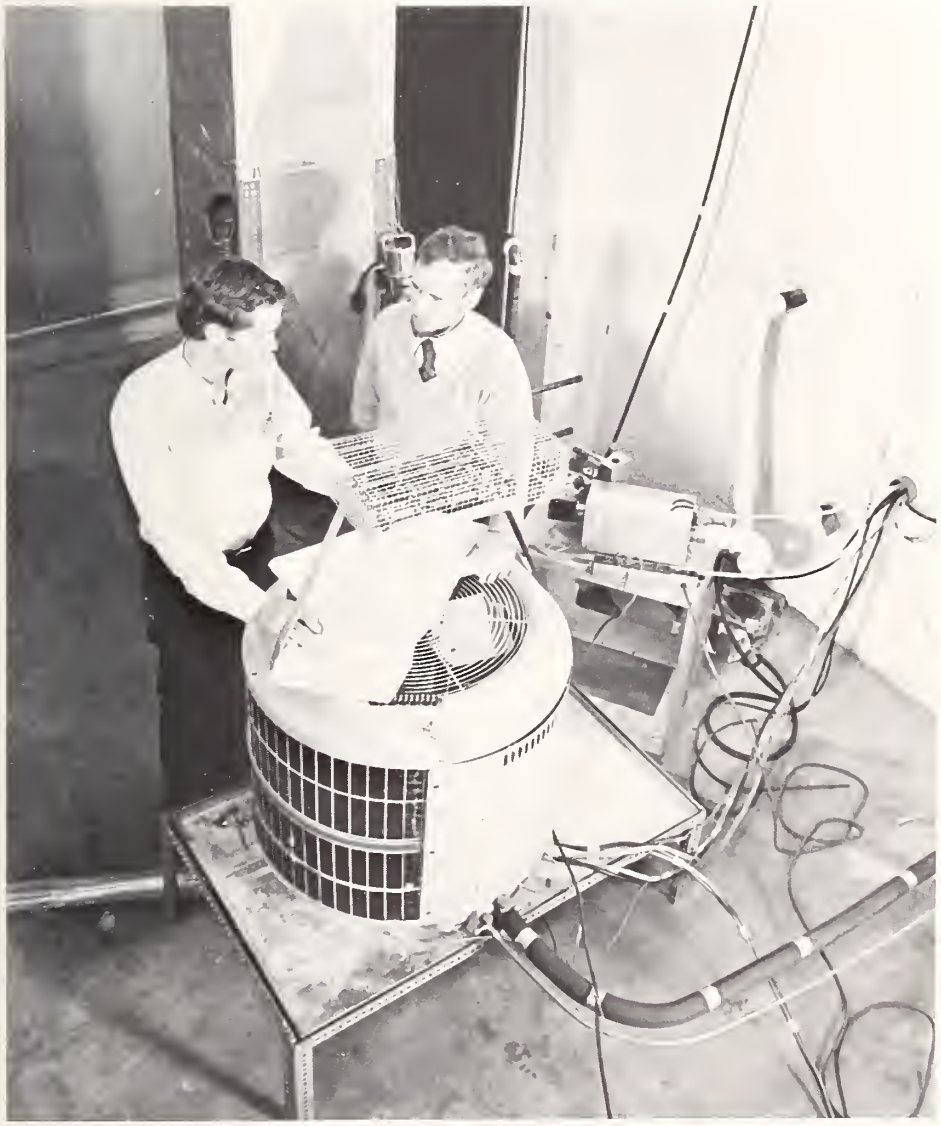
When analyzing performance data on solar equipment to see whether or not it meets standards or how it compares with other companies' products, is it first necessary to know where the equipment tests were run or who performed the tests? In other words, does it matter whether the tests took place in Phoenix or Seattle, or whether they were administered by a nationally-known testing laboratory or the equipment manufacturer?

Manufacturers, designers, and prospective purchasers of solar equipment need to know the answers to these questions. Helping in this task, NBS has been working in a DOE-sponsored program to speed the establishment of an accredited network of solar testing laboratories. The Bureau completed several major projects to that end. For example, NBS organized a round robin test of solar collectors involving 21 laboratories across the country to see how comparable the test results would be. Although differences were found among the testing laboratories' data, NBS determined that an analytical technique which compensated for the differences at various test sites could be used and would improve the validity of the data comparison.

As the popularity and use of solar energy systems grow, standards for solar energy testing procedures, materials, equipment, and performance are becoming more essential. At the same time, more attention must be given to coordinating the standards activities of Federal, State, and local governments, as well as professional, technical, and trade groups which set voluntary standards. Because of its close ties to Federally-run solar programs and to private sector technical experts and voluntary standards groups, NBS has served as a focal point in coordinating these solar standards actions.

Last year, the Bureau issued the second version of a plan for the development and implementation of standards for solar heating and cooling

NBS has developed test procedures for measuring the energy efficiency of various appliances. Engineers Walter Parken (left) and George Kelly discuss methods for testing heat pump efficiency, one of the Bureau's many projects to help other agencies implement provisions of Federal energy conservation statutes.



applications. Prepared by NBS specialists working in conjunction with the American National Standards Institute Steering Committee on Solar Energy Standards Development (an umbrella group of 23 organizations), the plan will help ensure that the needed standards are being developed with a minimum of overlap and duplication and that their implementation is orderly, effective, and inspires confidence in solar energy systems.

Energy Efficiency in Industry

Improving the efficiency of energy use is also an objective of the Center for Mechanical Engineering and Process Technology. In particular, this center is developing improved combustion measurement technology for new synthetic fuels, as well as for oil, gas, and coal. In September 1978, a model industrial furnace laboratory was put into operation and began to assist NBS researchers in studying the combustion process and the transfer of heat which takes place when fuels are burned in furnaces and boilers. The new laboratory will help the Bureau reach two related and important goals: improving current technology used to measure what actually happens in the harsh environment of utility and industrial combustors, and developing a way to predict what will occur inside these combustors.

There currently is a critical lack of information on the thermal effectiveness of high temperature industrial insulators, particularly refractory materials used in the walls of furnaces. Although many of these materials are exposed to and operate at temperatures above 500 °C, there are wide disparities in the thermal conductance values assigned to individual materials. If better information were available about the heat transmission of these insulating materials, engineers would be able to make more accurate calculations important in a wide range of thermal processes such as heat treating and primary metal production. The Center for Mechanical Engineering and Process Technology is addressing this challenge by preparing a computer program to model the heat flows within these materials. As part of this effort, a computer-controlled "hot wire" technique for measuring thermal conductivity of refractory and insulating materials for furnaces was developed. Less cumbersome and 10 times faster than commercially available techniques, the hot wire method automatically runs tests on the materials. This technique is aiding in the evaluation of a special high temperature Standard Reference Material for industrial testing equipment calibration.

This same NBS center has demonstrated the value of infrared thermography for assessing the energy losses of industrial furnaces and determining appropriate measures to make the furnaces more efficient. Infrared thermography involves use of a device much like a camera which takes photographs showing in different colors the hot and cold spots of the area being

examined. This technique has been used previously by NBS and others to obtain qualitative information about heat leaks and retrofit possibilities in industrial equipment and in buildings.

NBS engineers have now used infrared thermography for the quantitative measurement of heat losses in an industrial furnace, a significant accomplishment. Using an iron-casting foundry furnace, Bureau researchers were able to calculate accurately the amount of heat radiating through the furnace surface and being lost. Currently, engineers typically estimate, rather than measure, radiative heat transfer. With the more precisely calculated information obtained using infrared thermography, engineers computing the heat losses in furnaces can make more informed judgments about possible energy-saving measures.

With or without the advanced capabilities that infrared thermography offers, such "heat balances" are a fundamental step in any industrial energy conservation program. Last year, NBS prepared and distributed a practical "how-to" guide for performing such calculations: *Energy Management for Furnaces, Kilns, and Ovens.* (See page 71 for order information.)

Cleaner, More Efficient Utilities

In addition to developing methods and standards related to the use of new energy technologies by utilities as part of a major Federal Interagency Energy/Environment Program, NBS also has been active in other ways to bring about cleaner, more efficient utilities.

For instance, the Bureau has been providing the technical base for advancement of the related concept variously known as cogeneration, integrated energy systems, and MIUS (which stands for Modular Integrated Utility Systems). MIUS-type projects, for example, provide an option to package into a single processing plant two or more of the six utility services necessary for community development (electricity, space and water heating, air conditioning, solid waste processing, wastewater treatment, and residential water purification). Such plants are intended to recover energy that typically would be wasted by larger-scale conventional systems and are expected to minimize the environmental impact of utility systems.

NBS analyzed a MIUS "total energy" demonstration plant which provides electricity, heating and cooling to an urban residential/commercial complex in Jersey City, New Jersey. Acting in its role as a neutral, third-party evaluator, NBS instrumented the plant and collected the data necessary to evaluate the facility's energy conservation, economics, reliability, and environmental impact. Concluding that the plant is a viable and cost-effective system, the project for the first time provided detailed performance data and a thorough evaluation of an operating total energy plant. This information is needed so that equipment manufacturers, potential users like utilities and industries, government energy policy makers, and regulatory agencies can assess the potential benefits and risks of the MIUS concept.

The Center for Mechanical Engineering and Process Technology also completed an independent assessment of the design of a Federally-assisted MIUS installation planned for St. Charles, Maryland. Additionally, in its capacity as technical assistant to an international group concerned with the MIUS concept, NBS published an international catalog of more than 200 MIUS-type projects. (For more information on other Bureau energy and environment-related research, see "Safeguarding Environmental Quality," page 54.)

Better Utility Reliability and Performance

The Bureau has made several recent strides to improve the reliability of electrical power systems and avoid catastrophic breakdowns like the New York City blackout of 1977. The Center for Electronics and Electrical Engineering for the first time measured "Kerr coefficients" of two materials used in electric utility insulation systems. This determination is important because Kerr-effect measurements of electric fields and space charge contribute to a better understanding of phenomena that cause power cables and transformers to break down. These failures can occur either spontaneously over time or as a result of a catastrophic influence, such as lightning in the case of the New York breakdown. This better comprehension of breakdown-related phenomena is essential in advancing the electricity transmission and distribution technologies needed to accommodate a doubling of present transmission capacity within the next two decades.

In a related project, engineers from the same NBS group completed a joint effort with the Bonneville Power Administration, which serves the Pacific Northwest, to improve the tests which help predict how power systems will react during severe overvoltages. When a system is struck by lightning, for example, power company engineers must know how the power network will be affected. The tests now used to simulate such overvoltages are inadequate because simulated voltage surges cannot be measured accurately. In fact, some materials and equipment might withstand real-life lightning bolts but fail existing tests. The results of this joint research project will now permit better measurement of simulated overvoltages and clear the way for more reliable materials and power system performance.

NBS research has increased the technical data base for the Modular Integrated Utility System concept. The "total energy" system demonstration at this Jersey City site was instrumented and analyzed by Bureau engineers.

Also with the aim of improving the performance of electric utility systems, the Center for Materials Science put together a test program to evaluate synthetic porous polymer films for their potential usefulness as insulation in new energy-saving underground power transmission cables. Today, underground cable capacity is limited by the deficiencies of conventional insulation, so the possibilities of polymer insulation substitutes have become important. As part of a cooperative program in this area with DOE and the Electric Power Research Institute, this NBS test program will help measure qualities of the porous polymer insulation material which might lead to electrical discharges and eventual cable failure. This information will be particularly useful to polymer manufacturers in developing products with the insulating properties required by new underground cable systems.

In another project which required expertise in polymer chemistry and high-voltage measurements, NBS assisted DOE's Brookhaven National Laboratory in selecting polymeric tape for electrical insulation in a prototype superconducting power cable which that laboratory is designing for test purposes. Superconducting cables hold great promise as an economical, very high capacity means of underground power distribution. NBS became involved with this research effort since the special facilities needed for making the necessary high precision, low-loss measurements of candidate insulation tapes at cryogenic temperatures and operating voltages were not available elsewhere in the United States.

Promoting Better Use of Materials

Coping with Corrosion

The highway bridge spanning the Ohio River at Point Pleasant, West Virginia, gave no warning when it collapsed on December 15, 1967. NBS helped investigate that tragedy for the National Transportation Safety Board and performed some of the studies which later put the blame for the disaster on a shallow crack in the structure caused by corrosion. The human cost of this corrosion? Forty-six lives.

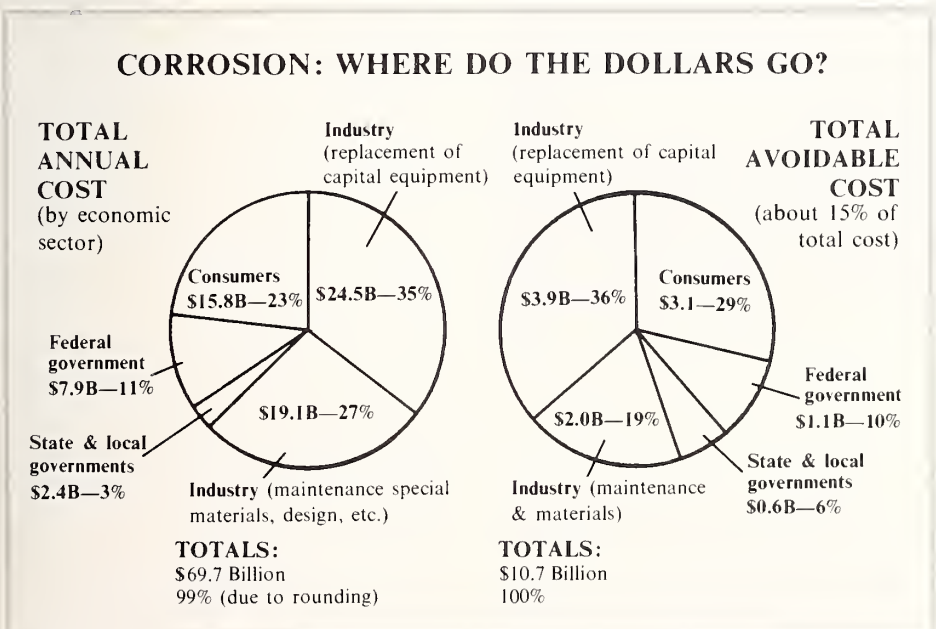
Corrosion also carries with it a tremendous economic toll. This destructive force ends up costing Americans in the neighborhood of $70 billion a year. There are ways to control it, but too often we fail to take the necessary precautions that would save large expenditures. This degradative phenomenon, which frequently is caused or hastened by the interaction of metals with air, water, chemicals, and pollutants, works persistently to shorten the lifetime and—as the Ohio River bridge fatally showed—sometimes affect the safety of structures and products.

The startlingly high estimate of the economic cost of corrosion was arrived at last year after the Bureau performed the most extensive study of metallic corrosion costs ever undertaken in the United States. Requested by Congress in recognition of the impact corrosion has on our economy, the study was an extension of the Bureau's research on corrosion as part of NBS materials science and engineering activities. The study drew upon the many technical disciplines that shape the NBS corrosion programs, including chemistry, physics, and metallurgy.

Bureau researchers quantified many of the previously uncertain impacts of metallic corrosion: expenditures to replace corroded materials and parts, costs of painting and other treatments to ward off corrosion, increased maintenance expenses, and higher payouts for corrosion-resistant materials. The Battelle Columbus Laboratories performed an important part of the economic analysis, incorporating a special modification of input-output analysis techniques that allowed the researchers to collect and evaluate the economic cost.

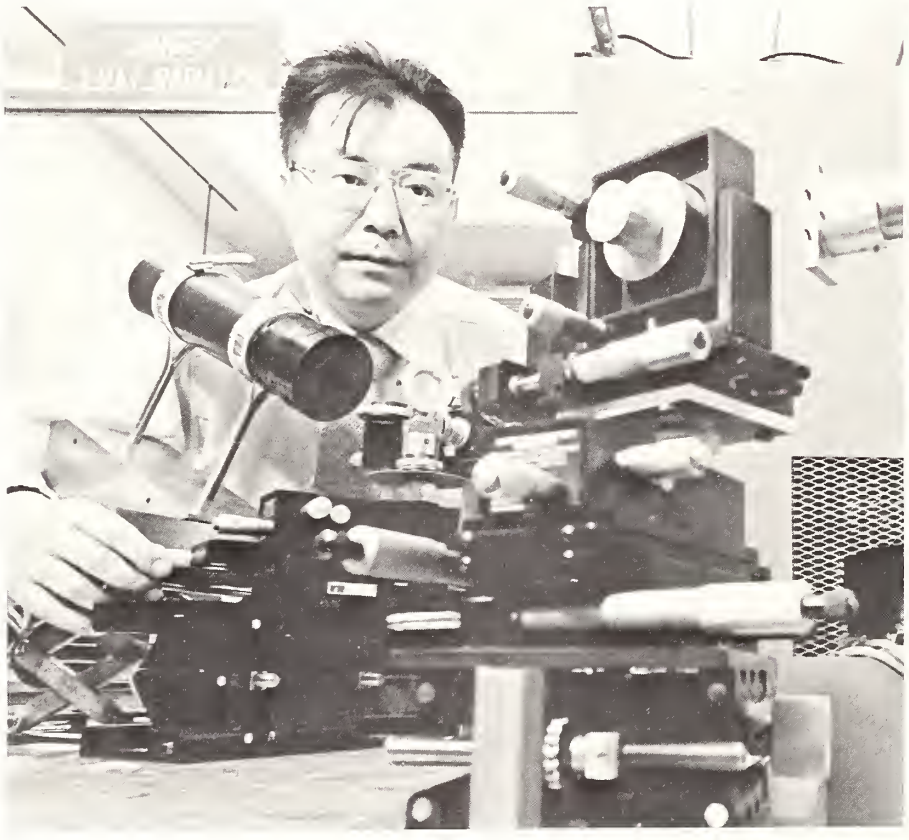
For the study year 1975, NBS estimated that corrosion cost automobile owners between $6 billion and $14 billion. The Federal Government was judged to lose $8 billion to corrosion annually, and the yearly corrosion bill for the electric power industry was estimated at $4 billion. A substantial portion of the cost of corrosion to the economy was deemed to be avoidable.

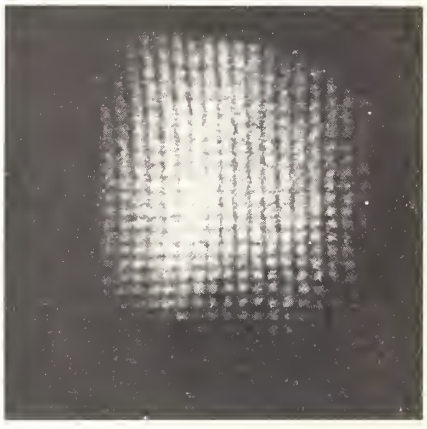
About $10.7 billion of the $70 billion total expense could be prevented by making the most economical use of currently available corrosion-control technology. This would not entail taking uneconomical steps to stave off corrosion; the savings estimate reflects only the most cost-effective combination of materials selection, design, preventive maintenance, and replacement. For instance, anywhere from $2 billion to $8 billion of the total cost incurred by car owners as a result of corrosion could be saved through the use of



At left is the disastrous aftermath of the Ohio River Bridge collapse at Point Pleasant, West Virginia. NBS studies showed that corrosion contributed to the catastrophe. The economic consequences of corrosion are highlighted in the charts above.

Nondestructive Evaluation





An NBS research team led by physicist Masao Kuriyama has developed a new device and technique for nondestructive evaluation that magnifies x-ray images on a real-time basis with significantly improved image resolution. Shown above is a radiograph of a lead-copper casting taken with the x-ray magnifier.

Today, many material and product failures that would otherwise occur are prevented through the detection of flaws and defects by nondestructive evaluation (NDE) techniques. NDE methods are used to inspect materials and components without damaging them in the process. Included in the NDE arsenal are some long-used and familiar techniques, such as x-radiography, as well as many relatively new methods. For instance, neutron radiography and acoustic emission are two NDE tools coming into their own. The Bureau's centers in the National Measurement Laboratory and the National Engineering Laboratory conduct a varied program to develop, improve, and apply NDE. The program is coordinated through the NBS Office of Nondestructive Evaluation.

One of the most significant NDE accomplishments at the Bureau in FY 1978 was the development of a technique and device for magnifying x-ray images on a real-time basis. Pictured here, the NBS instrument promises substantial increases in the productivity of industrial operations that require high-resolution x-ray inspection. Photographic enlargement of x-ray images provides this high resolution but is an inherently slow process not always compatible with industrial operations, where there often is an immediate need to know about the structural integrity of a material or product without waiting for the photographic development. On the other hand, real-time radiography—in which x-ray images are viewed immediately on a detection screen—has not been readily adapted to many inspection requirements because the images are not sharp enough to permit easy detection of small flaws.

Researchers in the NBS Center for Materials Science developed a way to overcome this problem in real-time radiography. Making use of two near-perfect silicon crystals, the Bureau scientists demonstrated an instrument that magnifies x-ray images and permits a 25-fold improvement in image resolution over the conventional real-time radiographic systems.

various anti-corrosion techniques and maintenance.

NBS was selected to perform the study of corrosion costs because of the experience it has gained in carrying out a variety of laboratory and field studies relating to materials and corrosion. Located primarily in the NBS Center for Materials Science, Bureau research in this area includes the development of new techniques for identifying and measuring corrosion as it is taking place and experimentation with methods likely to forestall this destructive force. NBS corrosion research often starts with the most basic materials science investigations and ends with the application of research results to solve everyday corrosion problems.

For instance, NBS has been conducting a series of experiments designed to characterize the corrosion process and its effects on metals buried underground. Data are starting to come in from one such project begun in 1970 when the American Iron and Steel Institute (AISI) began providing support to the Bureau for studying conventional and new stainless steel alloys for application in underground environments. These alloys are being considered for below-ground gas, water, telephone, and electrical distribution systems and for ground rods, culverts, or sewage disposal systems. But industry needs better information about how well these more corrosion-resistant alloys perform. AISI came to NBS because the Bureau operates a network of soil corrosion testing sites. The sites are unique in that the corrosive characteristics of the different soils at each site have been measured for more than 20 years. Work at these sites has helped NBS build a record of unsurpassed experience in soil corrosion test measurements.

In the AISI-sponsored program, Center for Materials Science researchers buried several thousand different samples of stainless steel alloys at six different sites across the country. Formed in a variety of sizes and shapes, the alloys were prepared to reflect the different service conditions under which they might be affected by corrosion processes. For example, some alloys were coated with protective materials, others were welded together, and still others were bent or placed under a load.

In FY 1978, test specimens that had been buried for 8 years were retrieved from several of the test sites and readied for evaluation by Bureau researchers. Along with the data to be accumulated from the remaining samples still buried, this information will lead to more reliable use of these materials in various underground applications.

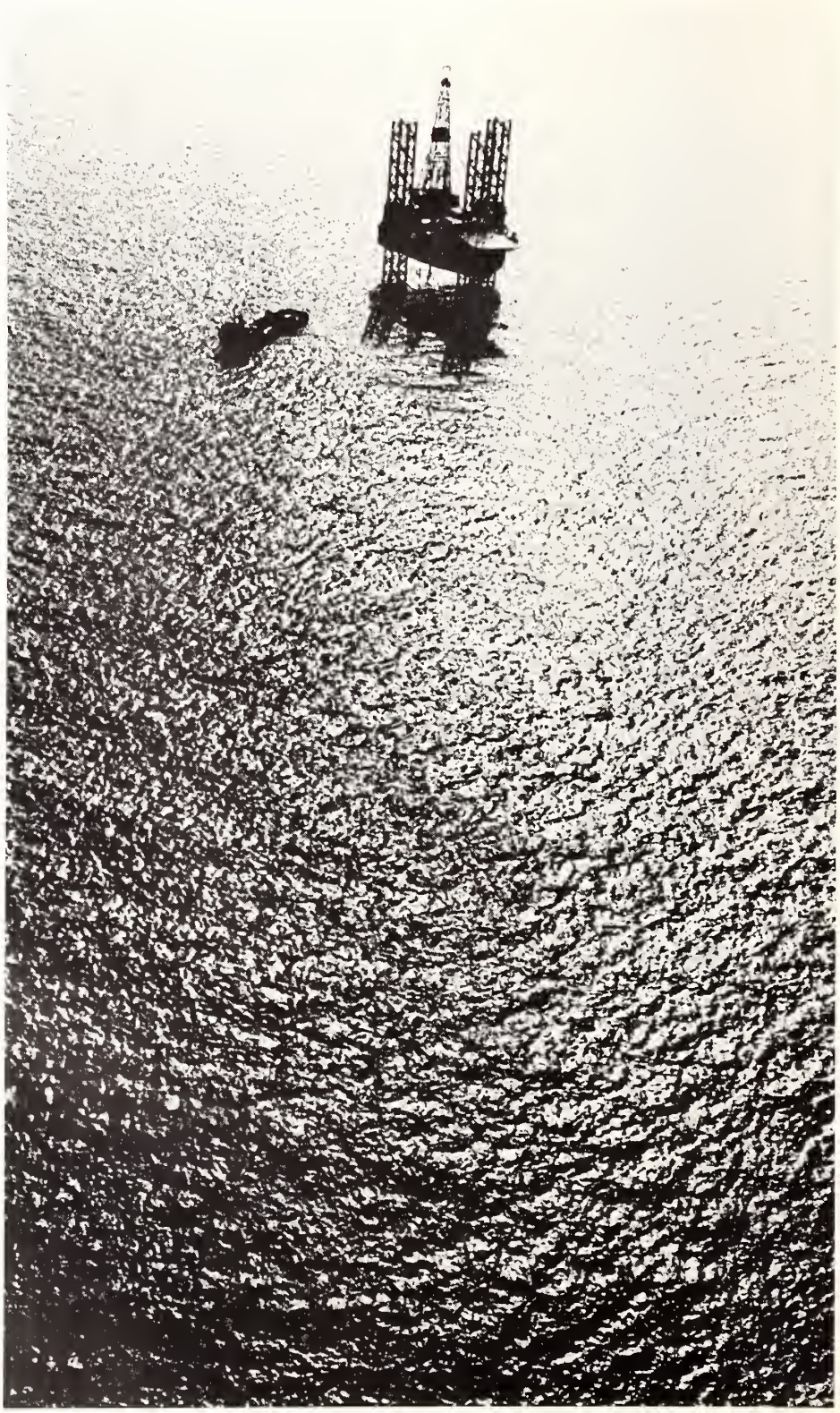
In a separate project for the Department of Energy (DOE), NBS made several significant advances in developing methods for the detection of corrosion conditions in buried concentric neutral cables used in electric power transmission. In the course of this research, NBS devised and tested successfully a new low-noise potentiostat, an instrument for measuring the electrical characteristics of the cable. These electrical measurements frequently are used in assessing the rate and type of corrosion taking place in metals. The Bureau's instrument is an improvement over commercially available potentiostats, since the electrical "noise" it generates is lower and thus interferes less than conventional instruments with the electrical measurements being monitored by the researchers.

NBS researchers also have been studying the role that alternating current leaking from power cables to the ground might play in cable corrosion. Last year, NBS developed mathematical models for determining the effects of leakage. From these models it was concluded that leakage does in fact speed corrosion under certain circumstances. This work has led to better tools for making more detailed, case-by-case examinations of the relationship between leakage and corrosion.

Corrosion strikes metals in the air and water, as well as those underground, and NBS also studies corrosion in these environments. In one of the longest-running NBS research programs, the Bureau has performed studies for the Naval Air Systems Command to determine the corrosion behavior of materials in use or considered for use in naval aircraft construction. This 50-year program—which concluded at the close of FY 1978—included analyses of the effect of variations in heat treatment on materials, galvanic corrosion caused when different metals are coupled, and the effects of organic and inorganic coatings and other surface treatments on metals. The resultant data are used by the Navy and other interested agencies to develop specifications for aerospace materials.

The increased use of offshore oil and gas drilling rigs and other metal structures in the search for energy below the sea has led to a greater awareness of the corrosive effects of this environment on steel. More than a quarter of a million tons of steel were put into use in new offshore structures in 1976 alone, and it is imperative that these materials be protected from corrosion. Again at the request and with the sponsorship of the American Iron and Steel Institute, NBS is studying the effectiveness of corrosion protection of steel in seawater. Thus far, protective systems examined have included metallic and nonmetallic coatings, materials used singly and in combination coatings, and cathodic protection. Cathodic protection involves taking advantage of basic electrochemical reactions to reverse the usual corrosion processes by which steel piles degrade.

NBS corrosion research starts with the most basic materials science investigations and ends with the application of research results to solve everyday corrosion problems. Corrosion protection for steel in seawater is just one of many areas being studied.



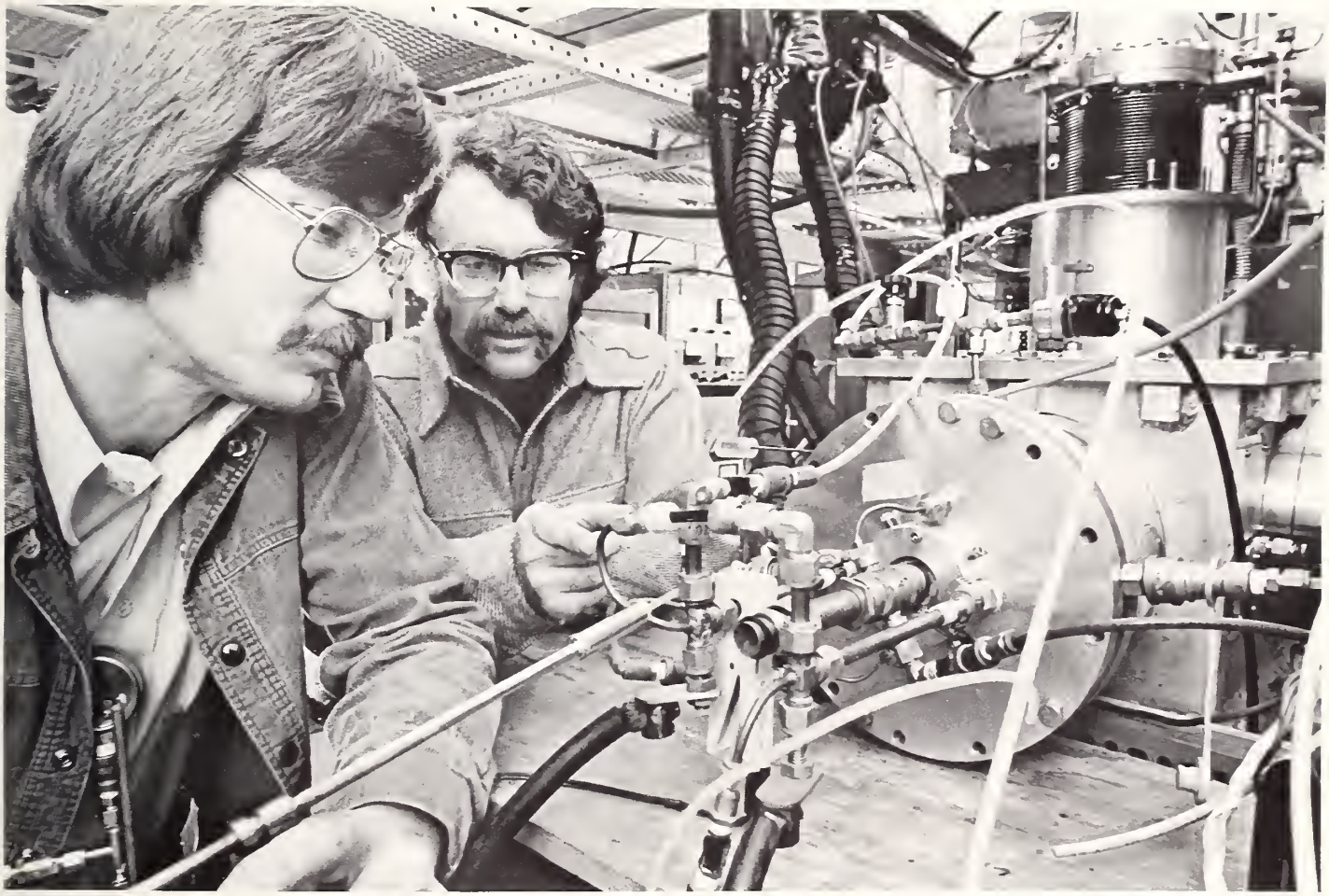
As part of the Bureau's effort to transfer technical knowledge gained from these research efforts to the consumer, NBS last year published and distributed a pamphlet for the general public on corrosion and corrosion protection. This new addition to the NBS Consumer Information Series, *Corrosion Facts for the Consumer,* explains different types of corrosion (galvanic, crevice, pitting, and stress) and provides practical tips for minimizing and preventing corrosion. It also contains guidelines for removing corrosion from household products and suggests the types of corrosion protection to look for when buying metal objects. (See page 71 for order information.)

The Materials-Energy Link

Solutions to many of the most important problems associated with energy conversion processes require research and innovations in materials science and engineering. Because of its strengths in this field, the Bureau is involved in the national effort to hasten the commercial availability of a variety of novel energy conversion technologies. Last year, NBS made advances in a number of areas critical to the progress of these materials-dependent processes.

In a continuing project carried out for DOE, the NBS Center for Materials Science has been evaluating the susceptibility of certain alloys to stress corrosion in high temperature gaseous atmospheres like those found in coal conversion plants. Stress corrosion can occur when a metal that has been formed by pulling or bending is exposed to a corrosive environment. A crack in the metal often results. Further progress has been made by NBS in applying a new technique developed in Britain, the "slow strain rate test," for judging stress corrosion tendency. NBS is concentrating on developing and refining the test method so that others can make

NBS research is contributing to a better understanding of the corrosion characteristics of materials used in high temperature gaseous atmospheres like those found in coal conversion plants. NBS chemists David Bonnell (left) and John Hastie have developed a new technique, transpiration mass spectrometry, to characterize corrosive gases.



decisions about which metals to rely on.

A related Bureau project seeks to provide better information about corrosive gases within coal gasification plants and about materials that can withstand the hostile environment found there. A recent development is "transpiration mass spectrometry," a technique devised and tested by NBS to detect and measure chemicals in the high temperature gases found within the plants. This method permits the direct measurement of molecules present in the gases under real-life situations rather than at the low temperatures and pressures at which the testing has had to be done until now. It also is the only technique that can identify and quantify each of the molecular species within the gases rather than just provide gross information on the total gas stream composition. With this new method, it will be possible to judge the corrosion characteristics of specific materials under extreme conditions. It is now being used to test the durability of materials for coal gasifier applications.

The Center for Materials Science also completed a year-long evaluation of how the materials used in a coal gasification pilot plant have held up. This plant in Rapid City, South Dakota, has been operated by DOE over a period of several years, producing low energy-content gas from lignite. The Bureau's evaluation of the condition of the plant's materials and components after exposure to this corrosive atmosphere has produced data which will be valuable to engineers designing full-sized coal gasification plants.

Other FY 1978 NBS accomplishments in the materials science and engineering area which are critical to promising energy conversion technologies include:

- utilization of new techniques to analyze catalyst failure due to poisoning by sulfur and graphite. Along with other surface science studies describing the behavior and properties of nickel catalysts more precisely, this research in the Center for Thermodynamics and Molecular Science is valuable to scientists and engineers developing processes for producing synthetic gas from coal.

Material Benefits

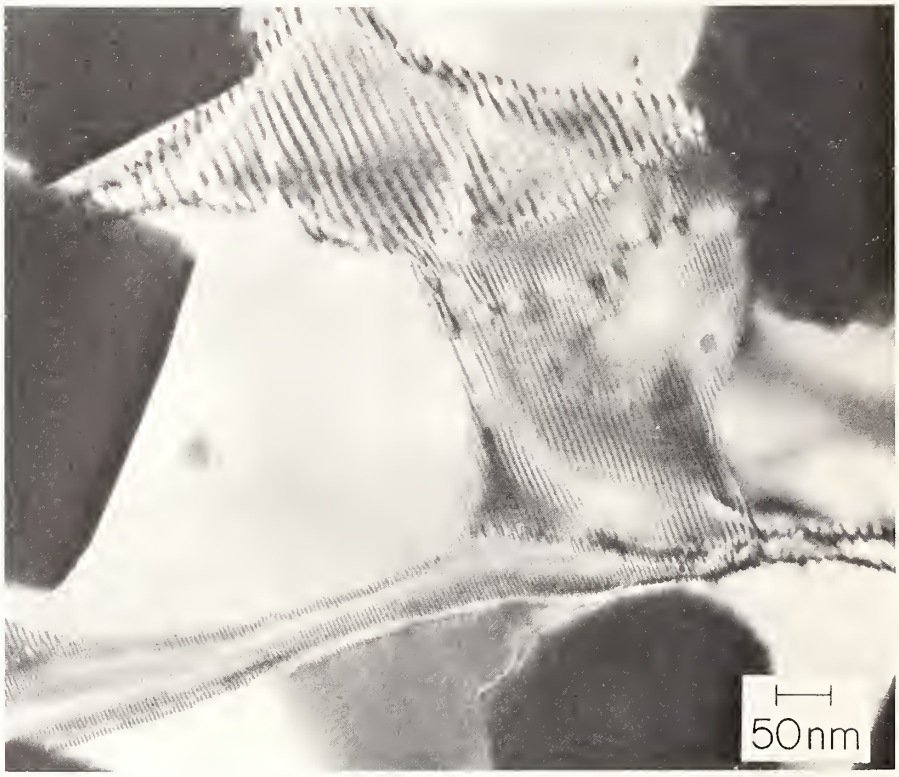
The Bureau's materials research responsibilities encompass all aspects of the materials cycle once the raw material leaves the ground: processing; design, manufacturing, and assembly; use; and recycling. Some of the other results of this major NBS effort in materials research which are not part of the energy-materials program are listed below.

- Significant progress was made in resolving a long-standing scientific controversy in theory relating the molecular structure of rubber to its mechanical properties. This was accomplished by researchers in the Center for Materials Science using the NBS nuclear research reactor in applying small angle neutron scattering.

- The American Society for Metals and NBS agreed to cooperate in establishing a phase diagram data program. Utilized by engineers in the selection, use, and processing of materials, phase diagrams are charts that show for a single metal or for combinations of metals the phases (liquid, solid, gas) that are present at different temperatures and pressures. These diagrams are important in the efficient use of metals in industrial processes and in efforts to improve productivity and cut costs. This program is administered by the Office of Standard Reference Data.

- The first 13 of a series of 18 Standard Reference Materials (SRM's) used in the processing of high purity refined copper were certified by NBS. Based on research in the Center for Analytical Chemistry, these SRM's will promote efficient refining and use of copper.

- An improved method for testing the abrasive wear rate of metals was developed that will lead to better data and decisions about the use and cost-effectiveness of wear-resistant coatings on such items as pumps, grinding chambers, and centrifugal separators. The method was established through the cooperative efforts of the American Society for Testing and Materials (ASTM), the NBS Center for Materials Science, and several industrial labs.



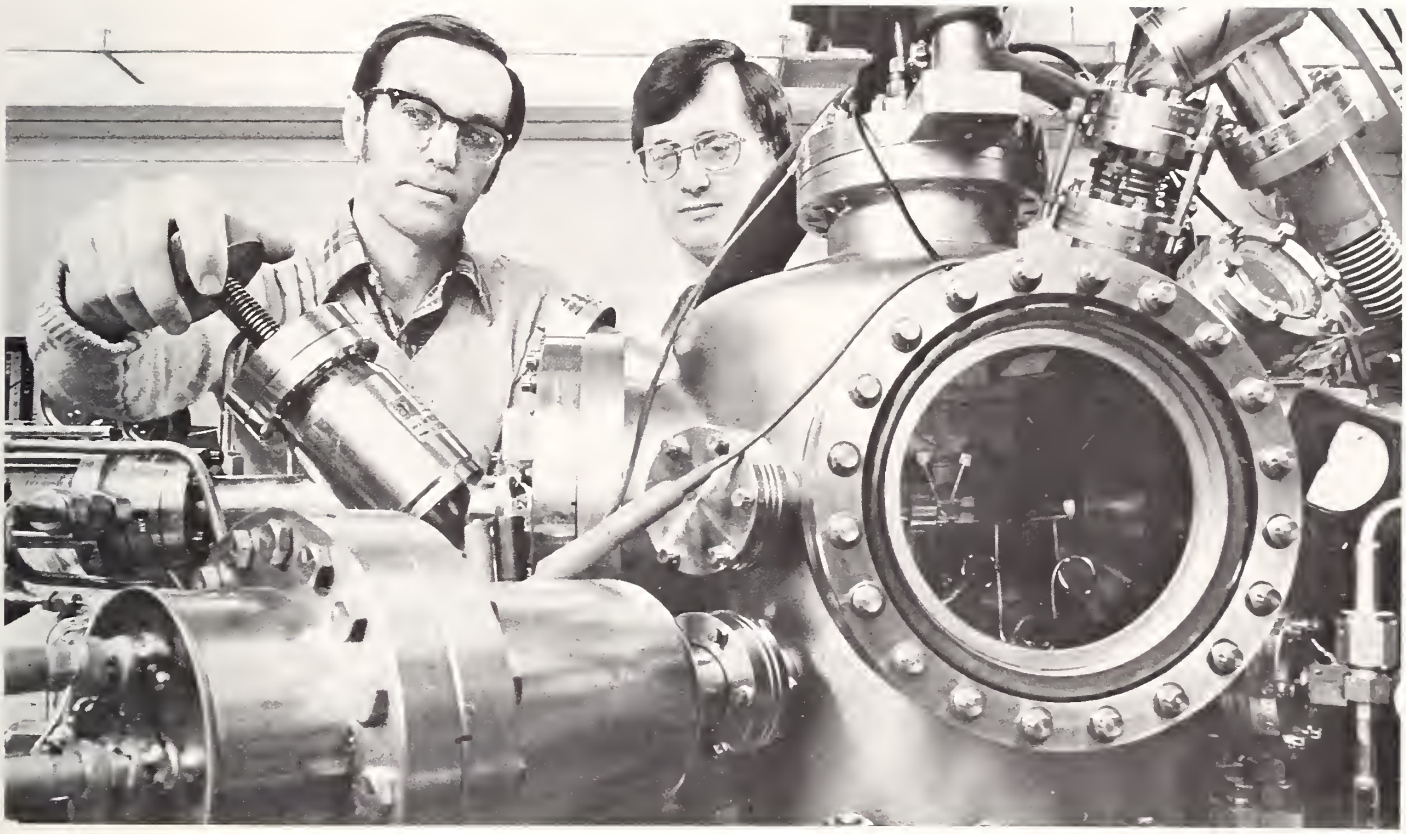
This transmission electron micrograph of a zinc-coated aluminum substrate indicates epitaxial deposits. The phenomenon is important in efforts to electroplate protective coatings on aluminum, which is being used to replace heavier metals. The Bureau's research provided the first evidence that a pure metal forms epitaxial deposits on aluminum.

- The first evidence that a pure metal forms epitaxial deposits on aluminum was found in the course of a Research Associate Program at NBS sponsored by the Aluminum Association. Epitaxy, a special matching of crystal lattices of metal and metal deposits, affects the adhesion and corrosion resistance of metal coatings on aluminum. Understanding this phenomenon is important in efforts to electroplate protective coatings on aluminum, which is finding increasing use in place of heavier metals as a means of saving energy through weight reduction (for example, in motor vehicles).

- Two new SRM's for wrought aluminum alloys were issued as part of an industry-ASTM-NBS program. They will improve quality control of the production of special alloys used in a variety of products, including trucks, marine and aircraft structures, railroad cars, and furniture.

- Also, two new steel SRM's were issued. One is for stainless steel, widely used because of its high temperature resistance to corrosion and scaling. The other SRM is for an important machine tool steel used in the production of bolts and screws. The Bureau was assisted by two ASTM-sponsored Research Associates in developing the steel and the wrought aluminum alloys SRM's.

The Bureau's surface science program tries to bridge the gap between catalysis at high pressures and surface science in ultrahigh vacuum. Richard Kelley (left) and Wayne Goodman are making measurements on nickel single crystals to learn more about the atomic effects of catalytic poisons and promoters.



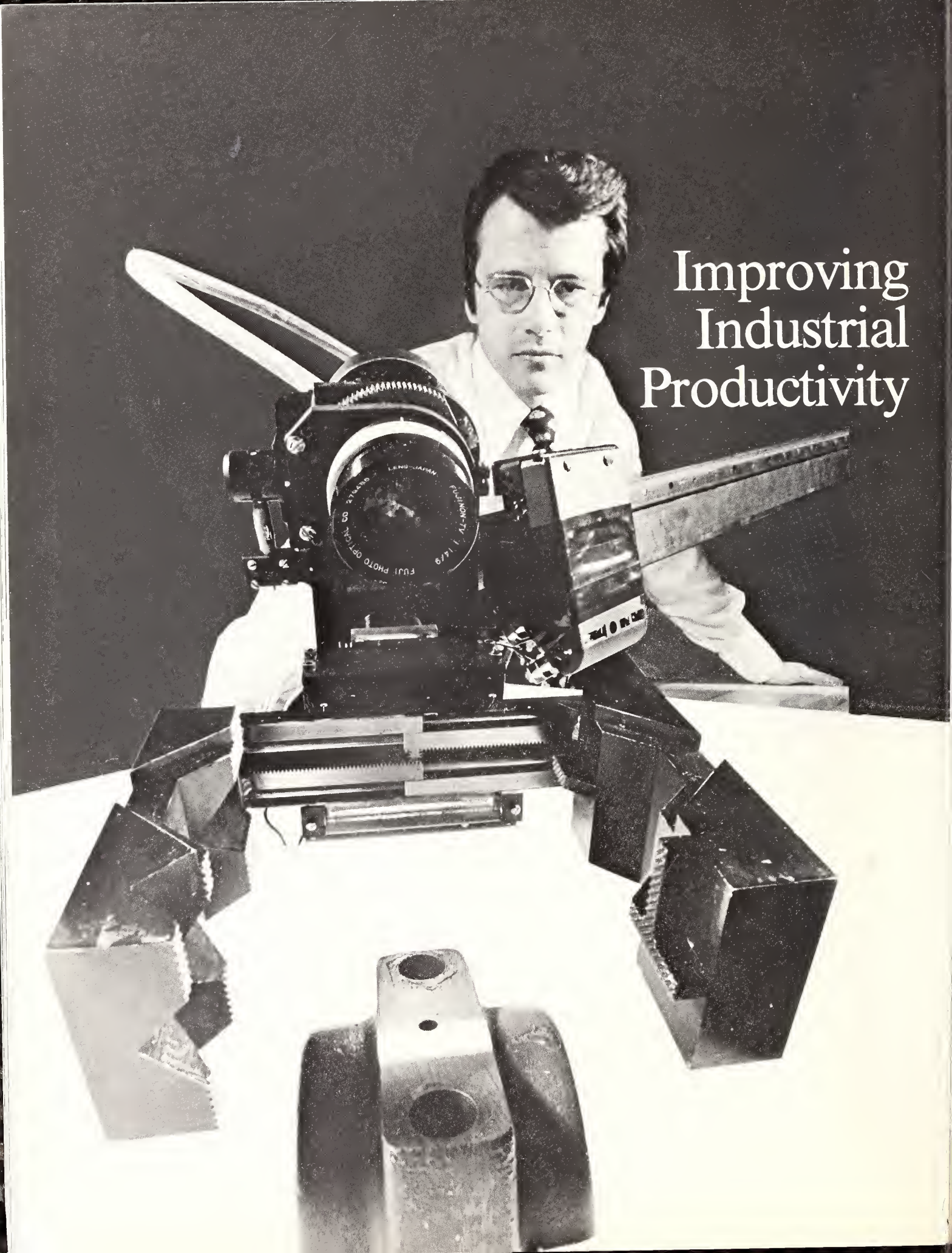
• construction of two new laboratory facilities for sampling and analyzing solid waste and refuse-derived fuels (RDF) that will help engineers determine the heating value of these energy sources. This is one of several materials-related projects being pursued at NBS to meet its responsibilities under the Resource Conservation and Recovery Act of 1976. Work in this area was performed by the Center for Thermodynamics and Molecular Science and the Center for Mechanical Engineering and Process Technology in conjunction with the NBS Office of Recycled Materials. This collaborative research is conducted in cooperation with the American Society for Testing and Materials and the American Society of Mechanical Engineers and is funded by DOE and the Environmental Protection Agency. It is expected to further the multiple goals of environmental protection and energy and materials conservation.

• application of a laser scanner to detect hairline cracks in photovoltaic solar cells that can degrade the cell's power output. In developing this detection method for DOE, engineers in the Center for Electronics and Electrical Engineering modified a scanner originally used to study high frequency microwave transistors and complex integrated circuits. It is now being used by the Bureau in a DOE-sponsored program on solar cell research and development.

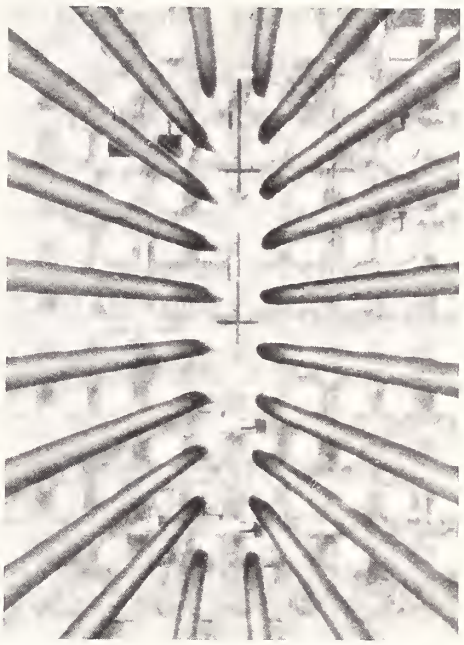
• gathering of the first atomic data from the NBS "Theta-Pinch" facility that produces plasma essential to magnetic fusion energy research. Specifically, this DOE-sponsored work conducted in the Center for Radiation Research has yielded information on the ionization rates of highly charged oxygen and nitrogen ions immersed in hot plasma. Another fusion project in collaboration with the Naval Research Laboratory and the DOE Los Alamos Scientific Laboratory produced information characterizing molybdenum impurities that are detrimental to the fusion power production process.

• determination of probable reasons to explain the failure of commercial temperature-measuring thermocouples. This research in the Center for Absolute Physical Quantities will aid efforts to develop coal gasification techniques. Synthetic gas manufacture has been slowed by the inability of these thermocouples to survive more than 100 hours at high temperatures.

• publication of the results of a study of the performance of materials used in solar thermal energy systems. This Center for Building Technology report provides direction to those developing standards for these materials.


Improving
Industrial
Productivity

As integrated circuits become smaller, production-line measurement technology becomes more important. NBS test patterns provide a means for improving yield and reliability. Above, needle-like probes measure electrical resistance and linewidth over an area 300 x 1600 mm (about 1/16 x 1/64 in.) on an NBS test pattern.



Advances in Semiconductor Technology

During the past year, a number of individuals and organizations took a long, hard look at the American capacity for technological innovation. Among their conclusions: The U.S. experience with semiconductor technology may be the signpost to this country's industrial future.

Semiconductor devices have become the basis for heightened global competition in an array of product lines, ranging from digital watches, pocket calculators, and "smart" appliances to the most sophisticated computers and military hardware control systems. Advances in semiconductor technology are a driving force behind this worldwide electronics revolution and U.S. efforts to improve industrial productivity.

It is the special significance to productivity and the critical role measurement science plays in advancing semiconductor technology that led NBS to establish a program in semiconductors. Based in the Center for Electronics and Electrical Engineering, this program aims to enhance the performance interchangeability, and reliability of semiconductor devices by developing and disseminating improved measurement techniques. The program is conducted in cooperation with the semiconductor industry and a number of Federal agencies that depend heavily on semiconductor devices.

The semiconductor industry routinely deals with the purest materials and the smallest dimensional tolerances of any industry. This fact alone would make it a natural area for the application of NBS measurement expertise. However, the situation has been complicated by the growing requirement for electronic controls with increasingly sophisticated capabilities, which demand that many operations be carried out at a high rate of speed. To provide these capabilities, manufacturers pack smaller microcircuits in greater numbers on individual integrated circuit "chips" made from semiconductor materials.

Making these individual circuit elements smaller offers great advantages, but also introduces a variety of design, manufacturing, and testing problems requiring specialized measurement skills. In most instances, the measurement sensitivity required usually equals or exceeds the present state-of-the-art. This means that measurement standards have typically followed rather than anticipated the semiconductor industry needs. Where the intuition of design engineers and production personnel once was sufficient to solve these problems, the smaller dimensions of today's microelectronic circuitry demand a greater understanding of the measurement considerations associated with the fabrication process and with the materials themselves. NBS recently registered a number of accomplishments that will help resolve some of the problems that the "small is better" semiconductor movement brings with it.

Because of systematic differences among manufacturers and laboratories—including different microscopes, measurement eyepieces, operating conditions, and personnel—there have been suspicions that linewidth measurements important to the fabrication process vary considerably from one facility to the next. As a result of a joint effort by two NBS groups, the Center for Electronics and Electrical Engineering and the Center for Mechanical Engineering and Process Technology, several microelectronics firms received for testing a new NBS photomask linewidth standard. Similar to the photomasks used to image circuits onto the semiconductor chip, the NBS standard comes in the form of a glass slide with chromium lines.

Data from the firms participating in the NBS-run test program vividly demonstrated the existence of large differences in measurements among

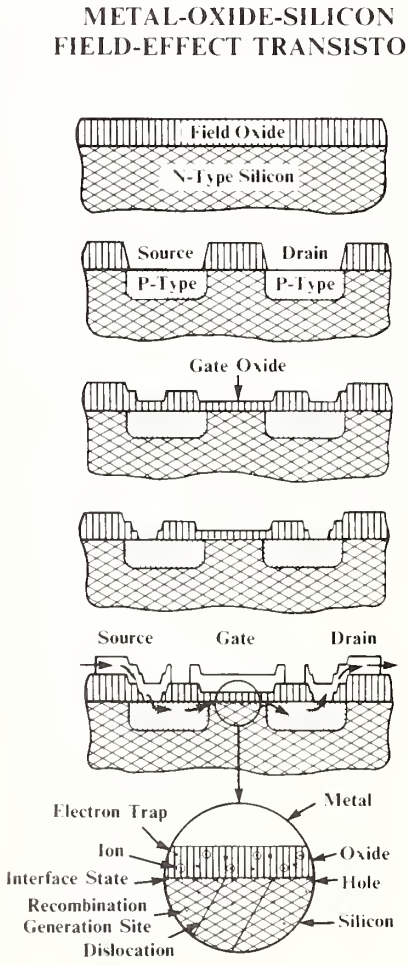
NBS engineer Gordon VanderBrug has developed a robot with a special vision system. The bar of light across the bearing block is produced by a strobe light mounted under the robot arm and is "seen" by its camera. The NBS vision system will help government and industry improve productivity by making more flexible robots available.

The Power of Semiconductors

Semiconductors are a class of materials that can conduct electricity better than insulating materials, but not as well as metals. Their special value as the basic material from which microelectronic circuits are made rests in our ability to control precisely their electrical properties by adding microscopic amounts of impurities at specified points. These controlled impurities change the electrical behavior of the material in those regions, creating electrically conductive areas between which the flow of an electrical charge can be controlled.

Two such areas sandwiching a third area of differing conductivity can serve, for example, as a transistor. This solid state electrical switch is capable of turning on and off a current that is large compared to the signal current which controls it. It operates far faster and for many more times than any mechanical device with moving parts. The fact that a small current may control a large one makes the device useful in the control of a multitude of industrial machinery and consumer products.

An integrated circuit "chip" less than 0.6 centimeter (one quarter of an inch) square with as many as 50,000 transistors in it can now do the work which previously required literally a room full of larger transistors. A pocket calculator running on two or three chips can perform the same functions as the first massive computer with relay racks full of vacuum tubes—and do the job much faster. What is more, the chip with thousands of elements is almost always as cheap to produce as a single transistor fabricated in the days before integrated circuits came into use.



REGION	PROCEDURE	MEASURED PROCESS VARIABLES
Wafer	Characterization	Resistivity, Dislocations Orientation, Flatness
Wafer	Clean Up	Residual Contamination
Field	Oxidation	Thickness
Source/Drain	Etch (Mask #1)	Linewidth
Source/Drain	Diffusion	Sheet Resistance, Lateral Diffusion
Source/Drain	Oxidation	Thickness
Gate	Etch (Mask #2)	Alignment
Gate	Oxidation	Thickness, Ions, Electron Traps Interface States
Contact	Etch (Mask #3)	Alignment, Contract Resistance
Metal	Evaporation	Resistivity, Thickness, Step, Coverage, Interface States, Electromigration
Metal	Etch (Mask #4)	Linewidth
Metal	Alloy	Contact Resistance, Junction Spiking Interface States
Wafer	Test	Threshold Voltage, Random Faults Leakage Currents (Lifetime) Circuit Yield

A single transistor is built up in a block of semiconductor material through a repetitive combination of chemical and physical processes. NBS research leads to improved measurements for the material and process variables that affect device performance.

In the NBS semiconductor fabrication facility, physicist Y.M. Liu encapsulates a microelectronic test pattern in an oxygen-free dry atmosphere, sealing it from moisture and contamination. This corresponds with the final step in the manufacture of an integrated circuit. Below, circuit design begins on an automatic digitizer.

companies using their regular non-NBS calibration standards and procedures. Consequently, NBS drew up plans to offer to the entire industry all the essential elements of a proper measurement system: a photomask linewidth standard and recommended procedures for evaluating, as well as calibrating, measurement instruments.

In another project designed to help overcome the problem of assuring that the microcircuit elements will work as expected without being able to test each of them, Bureau researchers developed a microelectronic alignment test pattern. The test structures are measured automatically with high-speed, computer-controlled equipment to determine whether or not the patterns are properly aligned. By using test structures such as this, which can be incorporated directly into microcircuit patterns, device manufacturers can get a good indication about the expected performance of that batch of circuits.

There have been several major Bureau accomplishments during the last year which will help in characterizing better both naturally occurring and intentionally introduced impurities in semi-conductor materials. For instance,

NBS researchers developed a sensitive instrument which, for the first time, made it possible to map the distribution of selected impurities over the entire wafer upon which integrated circuits are built up. Then, using this device, Bureau scientists showed the detailed density distribution of gold over a silicon wafer. (Gold is frequently introduced during the fabrication process to control the speed of electrical switching within the circuit.) The gold distribution map was found to correlate well with the leakage of current between individual circuit elements in the wafer. This development is particularly significant since leakage current affects the performance of completed devices. The Bureau device and the mapping technique provide a useful indirect, in-process means for monitoring leakage currents at an early stage in the manufacture of complex microelectronic devices, thereby helping to boost the yield of the fabrication process as a whole.

An unexpected phenomenon was observed in another Bureau project also designed to improve our ability to recognize and measure semiconductor impurities. While analyzing silicon wafers to ascertain the effect of sulfur atoms which had been bombarded into the wafer surface by ion implantation, NBS researchers discovered the existence of a shift between the deep energy levels of two isotopes of sulfur. This had not been observed previously and is expected to provide valuable insight into the theory of impurities in semiconductors. The discovery was made possible by significant Bureau advances in the introduction of sulfur impurities by ion implantation and in thermometry at cryogenic (very low) temperatures. Along the same lines, scientists working in the NBS semiconductor technology program began exploring exotic new methods for characterizing the impurities in semiconductor material at exceedingly low concentrations (less than one part per billion), including an advanced technique known as resonance ionization spectroscopy.

One of the NBS semiconductor program's most successful troubleshooting projects, which addressed the problems associated with wire bond connections, reached a final milestone last year with publication of a report on industry wire bond tests. Nearly all microelectronic devices rely on bonded

wire connections linking the integrated circuit chip with the other parts of the product. Breakage in the bonds, however, has been a major cause of device failures. At the request of several military agencies which were especially concerned with these failures, the Bureau began research on the wire-bonding problem in the late 1960's and uncovered various defects in the design of ultrasonic bonding machines then in use.

The NBS work fostered a more fundamental understanding of the bonding process, enabling the industry to modify production bonding equipment and techniques and to achieve higher reliability. The Bureau's studies also led to a new nondestructive method for testing the strength of individual bonds which identifies poor connections without damaging adequate ones. This method has been incorporated into voluntary standards of the American Society for Testing and Materials and has had a profound impact on the fabrication of microelectronic devices using wire bonds. The NBS contribution made possible very large hybrid devices with 500 or more leads, and, where manufacturers were experiencing an average of one bond failure in each circuit, the Bureau's method provided a means of testing that could reduce field failures from bonding defects down to zero.

Moving on from this work, NBS engineers have been experimenting with a technique for testing the strength of connections made by a newer method, tape carrier bonding. The Bureau's test works by applying a precise amount of stress and then recording the ultrasonic "sounds" emitted from the bonded surfaces. Like the other projects in the Bureau's semiconductor technology program, this research is designed to provide the tools necessary to improve the performance of microelectronic devices—and thereby boost the Nation's productivity levels.

Physicist Robert J. Hocken is shown in the Bureau's 3-dimensional metrology laboratory. NBS helps develop the advanced measurement techniques needed to bring about more efficient materials use, greater quality assurance, and higher productivity rates associated with more sophisticated industrial machinery.

Automation and Robots

A significant portion of all goods manufactured in the United States is turned out by companies producing in small lots or batches rather than in mass quantities. Accounting for more than one-third of manufacturing's share of the gross national product, these discrete parts or batch process manufacturing plants represent a vast opportunity for productivity improvement through the rational application of automation techniques. Moreover, in addition to improving quality control and efficiency, selective automation could also enhance workplace safety by removing the worker from hazardous environments.

The work performed by NBS researchers who are developing sensitive new techniques and standards for industrial robots and other automated machinery will help batch manufacturers achieve some of the potential productivity and workplace improvements. Robots used in industry today are worlds away from the android characters made so popular by science fiction movies. The great majority of these robots are simply mechanical arms which can be programmed to perform repetitive tasks. Their relative inflexibility makes them too expensive to be used except when products are being fabricated in quantities far exceeding those which batch manufacturers are used to.

One of the major problems contributing to the inflexibility of these assembly-line robots is their lack of "sensitivity." If the objects they are to process are not placed precisely in the spot that has been programmed into their memories, the robots are likely to shove, crush, or miss the objects. For several years, engineers in the Center for Mechanical Engineering and Process Technology have worked on devices and controls designed to let robots sense and adjust to the locations of the objects they are to handle. NBS is now at the forefront of this robotic sensory technology.

At the request of the National Aeronautics and Space Administration, NBS last year designed and built a vision system for a manipulator arm which uses a solid state camera and flash unit. When light is flashed into the area in front of the arm's "fingers," the camera conveys the shape of the object

it views back to the operator. NBS has duplicated the "proximity" vision system and is coupling it to a computer that can "read" the information and relay adjustment instructions back to the arm. This kind of work will help both government and industry improve the productivity of their operations by making more flexible robots available. By avoiding the expense of having to build costly transfer lines to ensure precise placement of objects before the robot arm, such vision systems will compensate for the robot's inability to "see" and make this type of automation more useful and economically attractive to batch manufacturers.

Under a contract with the U.S. Air Force, NBS also began work on a project to develop an integrated computer-aided manufacturing (ICAM) facility that could revolutionize the production of aircraft parts and cut manufacturing costs drastically through increased productivity. Aimed at the batch processing aerospace industry, but applicable to other discrete parts production as well, the ICAM system is intended to use computers to organize every step of the manufacturing process—from parts design and physical placement of machine tools to parts shipment—in the most efficient and economical way. Bureau engineers are establishing guidelines for the selection of robots, robot computer languages, and robot control systems and are providing technical support for developing and implementing robot control systems, programming languages, and sensory processing systems.

NBS last year expanded the "3-dimensional metrology" laboratory facilities which it uses in automation studies intended to increase the measurement accuracy and processing capabilities of industrial machinery. The measurement techniques developed in this facility will be applied to numerically controlled machine tools in order to improve accuracy, aid interchangeability of parts, and reduce the cost of small batch manufacturing operations. More precise measurement, by cutting and punching machines, for instance, means more efficient materials use, greater quality assurance, and higher productivity rates.

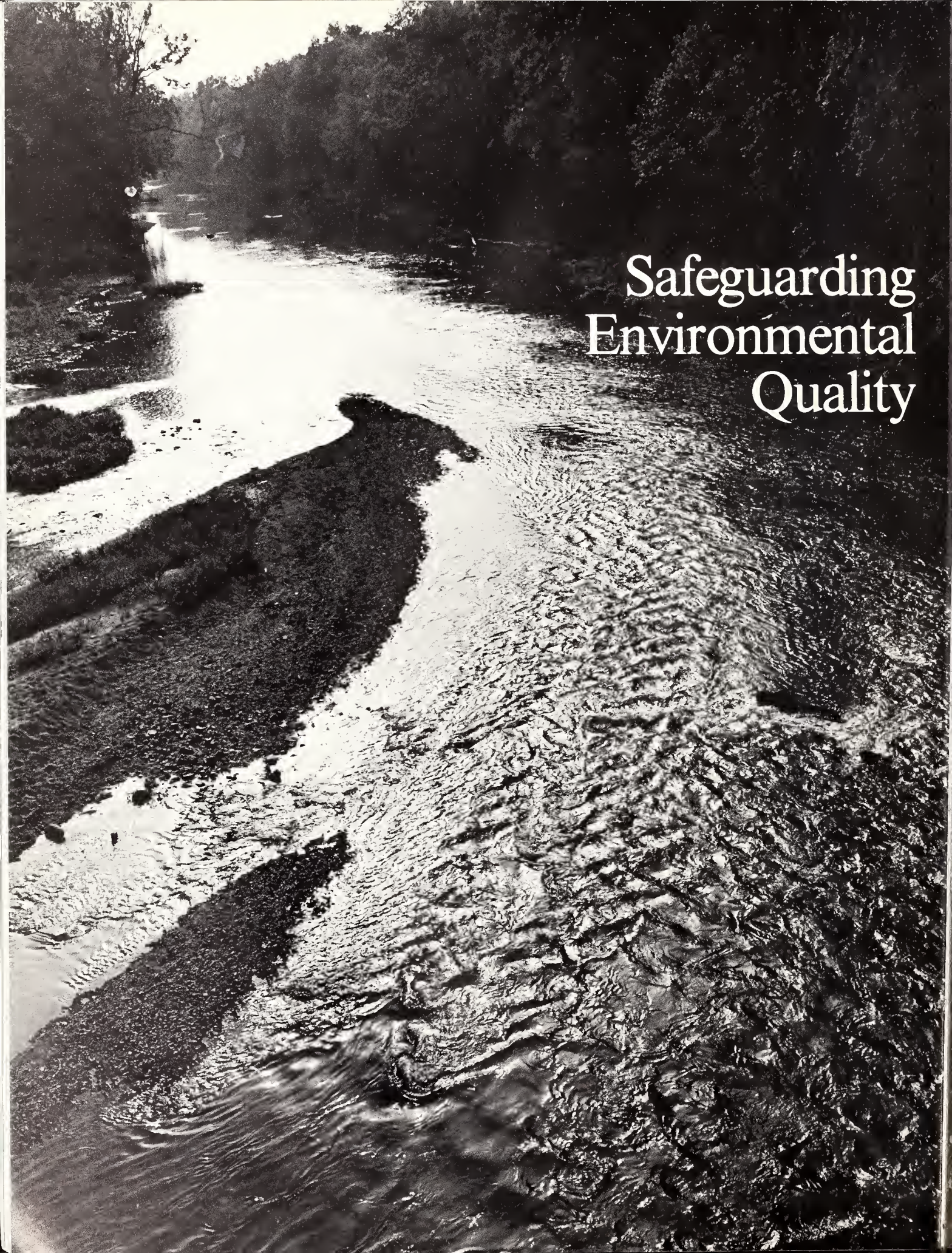
Technological Innovation

In FY 1978, the Bureau established a new office to study the desirability and feasibility of creating a "cooperative technology" program that would stimulate joint efforts by the Federal government, industry, and academia in developing the science and technology base critical to U.S. industry. Working in support of the Department of Commerce's Office of Science and Technology, the NBS Office of Cooperative Technology has been examining the proposition that Federal involvement may be appropriate in catalyzing industry and government efforts in areas where firms find insufficient private return to perform the needed work. Such situations may arise in: emerging technologies which promise to lay the base for new industries, but in which new firms have not yet generated sufficient economic strength to support long-term exploration; fields of technology which are broadly applicable to industries and in which no one firm has the expertise or economic interest to underwrite advances that would span more than one sector; and disaggregated industries made up of many firms which are not sufficiently large to support or adequately benefit from R&D.

To examine industrial needs and possible program designs, NBS performed several studies, including an examination of related programs in this country and abroad, that are aimed at encouraging technological innovation. The Bureau conducted discussions with leaders in university and industrial research organizations about particular technologies where special Federal attention might catalyze new research and innovation. Welding, corrosion, radiation processing, semiconductors, flexible manufacturing systems, and textile technologies were among the topics investigated in case studies. The NBS study will be concluded in 1979, followed by a Commerce Department decision about whether or not a cooperative technology program should be launched.

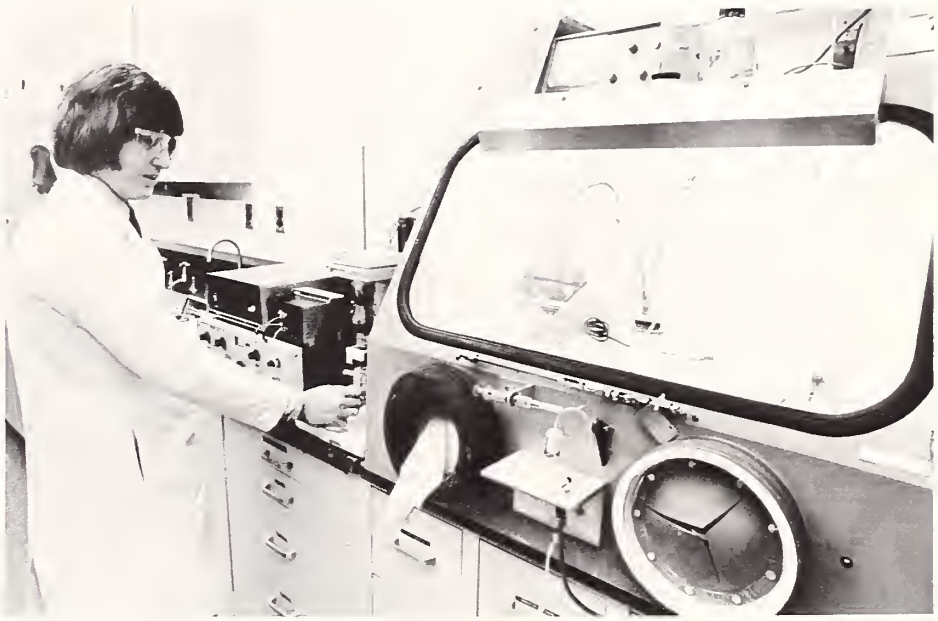
The theme of improving industrial productivity can be found throughout much of the work performed at NBS and reviewed in this report, and much of it has to do with technological innovation. In addition to carrying out laboratory-based research which often encourages and leads directly to innovation within industry, NBS also devotes a substantial effort to analyzing how Federal, State, and local government programs and policies may stimulate innovation.

Continuing its research in this area, the Experimental Technology Incentives Program (ETIP) in the NBS Center for Field Methods last year published a report on the management of Federal research and development activities. This report recommended methods for ensuring that the results of Federally-funded research and development are "commercialized" in the private sector. ETIP also completed an indepth study providing insights into the $25 billion annual Federal subsidy activity affecting capital formation. The resulting eight-volume document, *Subsidies, Capital Formation, and Technological Change,* suggested ways in which Federal managers can use this subsidy power to spark technological change.



Safeguarding Environmental Quality

Solutions of biological materials are analyzed for toxic organomercury species by research chemist William MacCrehan. Also pictured are an electrochemical cell and samples of shark, tuna, and oyster tissues to be tested.

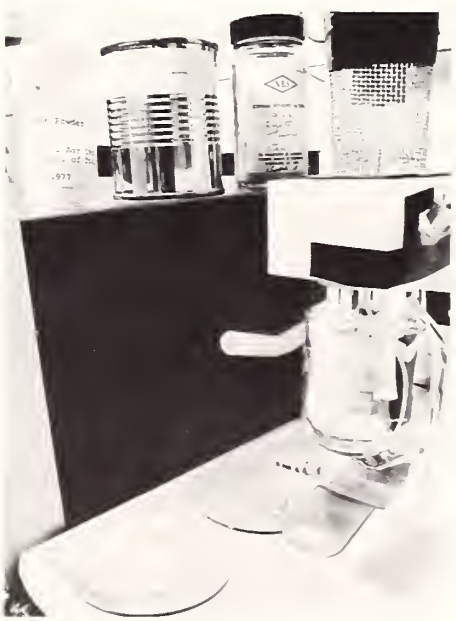


Measuring Toxic Chemicals In Water

Tracking down toxic substances that are present in our environment only in minute or "trace" amounts—sometimes in the parts-per-billion range—is a difficult enough task. Finding ways to measure the amounts of these hazardous pollutants to a high degree of accuracy puts our most sophisticated scientific measurement methods and equipment to an even tougher test. NBS has operated a decade-long program to supply the improved measurement techniques and standards necessary for safeguarding the Nation's environmental quality. Since our physical environment and the contaminants that degrade it are so closely tied to our personal welfare, this Bureau effort represents another of the ways in which NBS is working to protect public health and safety.

The NBS environmental measurement program has led to the development, production, and distribution of more than 75 Standard Reference Materials (SRM's) for use in environmental chemical analysis. Coordinated through the Office of Environmental Measurement, this combination of SRM's and other environmental research activities at the Bureau offers the Nation's researchers and pollution abatement experts the tools to ensure reliability in measurement and to facilitate related science and technology advances.

Scientists in two NBS groups provided one such tool when they developed a new technique for standardizing measurements of a class of materials called polynuclear aromatic hydrocarbons (PAH's). These compounds are of special interest to environmental and energy researchers since many PAH's have been demonstrated to be carcinogenic. Naturally occurring in fossil fuels, PAH's are closely associated with several important energy technologies, including the production of petroleum and shale oil and coal liquefaction and gasification. Their special threat to our water resources is linked directly to the nature of those technologies. PAH's may be introduced into the marine environment via oil spills during drilling operations or tanker mishaps. They also may find their way into water in the aqueous effluent from coal liquefaction and gasification operations.



In order to measure accurately the concentrations of PAH's found in any single water source, laboratories need

Engineering technician James Suddueth (standing) and Research Associate Robert Miller prepare to analyze gaseous Standard Reference Materials using a computer-operated gas analysis system developed at NBS. At right, engine exhaust from a new automobile is measured at an EPA facility using NBS-recommended techniques.

an SRM for comparison. But measurement of PAH's poses special problems. First, their low solubility in water makes it impossible to use the more traditional techniques for preparing accurate chemical measurement standards. In conventional standards, known quantities of the chemicals to be measured are typically dissolved in a solution, which is then analyzed and can be packaged for use in calibrating laboratory equipment, evaluating samples, or performing research. But when PAH's are placed in water, they tend to adsorb onto the walls of storage vessels and tubing of the laboratory equipment. Moreover, since they are carcinogenic, they are dangerous to handle. This means that special care needs to be taken in working with these chemicals so that they do not enter the laboratory environment.

Scientists in the NBS Center for Analytical Chemistry and the Center for Thermodynamics and Molecular Science last year discovered a way to overcome these difficulties. Glass beads coated with PAH's were packed in short stainless steel tubes. Saturated solutions of PAH's were first generated by pumping water through a tube and were then analyzed, enabling NBS to certify the stainless steel tube and its contents as a new SRM. The generation of small quantities of known concentrations of PAH's within the tube ensures instrument calibration while limiting both environmental contamination and exposure to the laboratory analyst.

The full significance of this development goes far beyond the provision of an SRM for polynuclear aromatic hydrocarbons. As part of the Bureau's work in a special national program of research about the environmental implications of energy production and use, this technique now opens the door to the generation of SRM's for the whole range of toxic organic chemicals found in water. For instance, the method also may be applicable to the measurement of pesticide compounds that are otherwise difficult or impossible to measure.

Also in the quest to provide more precise measurements of environmental contaminants in water, NBS last year developed SRM 1643, Trace Elements in Water. This SRM is already helping State environmental and public health scientists to evaluate the accuracy of trace element measurements in filtered and acidified fresh water. It also is useful for calibrating instrumentation used in making these determinations. The SRM was prepared using high purity water and 23 elements to simulate the elemental composition of natural fresh water. The Environmental Protection Agency (EPA) has set maximum contaminant levels for a number of the elements contained in the SRM under authority provided by the Safe Drinking Water Act enacted in 1974.

The potential for using new electrochemical techniques to reveal in more detail how toxic chemicals travel through our environment was vividly demonstrated last year in the Center for Analytical Chemistry. Bureau scientists working in cooperation with the University of Maryland coupled two

traditional yet separate techniques used by chemists—liquid chromatography and differential pulse electrochemical detection—to identify and measure methylmercury, a toxic organometallic substance. Conventional analytical methods can be used to measure the total mercury content in an environmental sample, but it is the organometallic mercury species which are deemed most harmful. This NBS-applied hybrid technique allows laboratory researchers to determine selectively the toxic forms of mercury. Bureau scientists used this method during FY 1978 to measure the methylmercury levels in tuna and shark meat.

On Land, in the Air

The Bureau's environmental research and measurement programs also address the problems of pollutants on land and in the atmosphere. In FY 1978, for example, the Center for Materials Science devised a new method to separate and measure individual organic derivatives of tin and arsenic at trace concentrations in soil as well as in water. These derivatives often are contained in herbicides, antifoulants (like those used to slow the growth of barnacles on hulls of ships), and a variety of pesticides. By combining traditional chemical separation and detection techniques—liquid chromatography with graphite furnace atomic absorption or with an ultraviolet detection technique—NBS researchers demonstrated a vastly improved method for analyzing metal-based biocides in the environment.

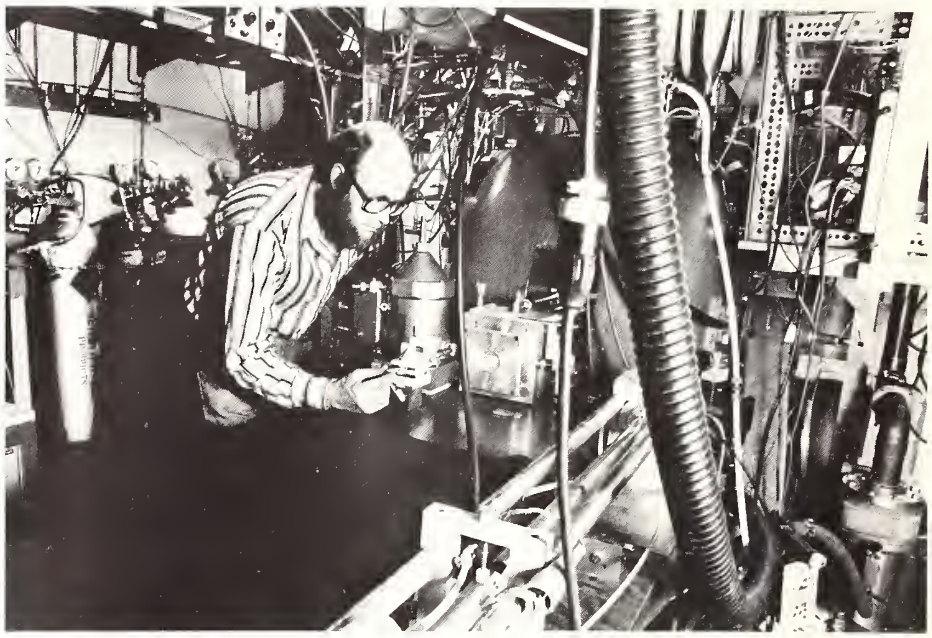
This Bureau innovation permits the measurement and characterization of individual elements in the parts-per-billion range and provides greater sensitivity than conventional measurement methods. It also allows quicker evaluations and does less damage to the sample being analyzed, which means that the sample can be used again for other tests. With this method, researchers can follow the progress of these materials as they degrade, are transported, and concentrate in parts of the environment. They can also observe the transformation of what may be a relatively harmless herbicide, for instance, into a toxic or carcinogenic form.

The first phase of another Bureau project important for safeguarding both land and water resources was completed in FY 1978 when NBS researchers developed test procedures which can be used to compare recycled oils with "new" (virgin) oils. This effort by the Office of Recycled Materials will encourage the reuse of once-used oil which would otherwise be wasted or possibly become a serious environmental hazard if dumped into sewers, rivers, or landfills. The NBS test procedures were called for in the Energy Policy and Conservation Act enacted in 1975 and are to be used to establish the "substantial equivalency" of recycled oil with virgin oil for each potential end use. The Bureau's test procedures are being provided to the Federal Trade Commission, which will then remove certain restrictive labeling requirements for recycled oils that can pass the tests. This should enable recycled oils to compete more effectively with virgin oils in the marketplace.

The Bureau's measurement capabilities are also applied in controlling air pollution from automobile exhausts and achieving Federal clean air standards. And since auto fuel economy ratings are calculated on the basis of exhaust gas measurements, NBS measurement skills are also important in this facet of Federal automobile standards concern. Along these lines, several advancements in auto exhaust analysis were made in FY 1978 at the Bureau, which has been providing SRM's and performing research in both automobile fuel economy and pollution measurements for a number of years. Through an agreement signed last year, the Bureau is assisted in its development and production of SRM's in this area by a 2-year Research Associate Program sponsored by the Motor Vehicle Manufacturers Association. The program aims to develop and produce 26 new gas SRM's for use in establishing the accuracy of motor vehicle emissions tests, with primary emphasis

NBS research on the atmosphere ranges from studies at ground level to the upper regions. At top, physicist Ken Evenson adjusts a laser magnetic resonance spectrometer used in a project that has helped to revise estimates of how ozone levels are affected by fluorocarbons and supersonic transports.

The lower photo shows particulate matter in an urban air specimen as seen through an NBS electron scanning microscope. Urban air particulates are among the Standard Reference Materials that NBS is developing to help in monitoring air quality.



on measurement of emissions from heavy duty engines.

An automated gas analysis system for the certification of primary gas mixture SRM's was developed last year in a project cosponsored by NBS and EPA. Termed COGAS, for computer-operated gas analysis system, the arrangement is designed to sequentially sample and analyze up to 25 cylinders of a given gas mixture without supervision. COGAS has permitted a substantial reduction in the costs associated with SRM certification, while also producing a larger, more precise data base upon which the absolute gas concentration is derived. With slight modification, the system can also be used by other Federal agencies, State governments, and motor vehicle manufacturers as an instrument to significantly reduce the labor requirements in exhaust sampling and analysis.

Also in the area of auto emission testing, a long wavelength acoustic flowmeter was invented for measuring the rate of exhaust flow from the tailpipe of an automobile or truck. Linked with pollutant concentration detectors, this flowmeter could be used on production lines and in State and local test stations to determine compliance with EPA emission regulations. There is no competing technique for measuring the exhaust flow rate and the NBS device could eventually replace conventional testing equipment, which is comparatively expensive and cumbersome. Moreover, the flowmeter could provide more accurate information and be operated by unskilled personnel. Developed in the Center for Mechanical Engineering and Process Technology in cooperation

with the Office of Environmental Measurements, the flowmeter may also have applications in developing fuel-efficient engines or in medical research for measuring human or animal breath flow rates.

In addition to auto-related pollution, the Bureau also addresses measurement needs associated with other sources of air pollution. For instance, NBS issued a sulfur dioxide SRM useful in measuring the pollutants from fossil fuel power plants. Also in FY 1978, Bureau researchers developed a nitrogen dioxide SRM which will be used to analyze emissions from nitric acid plants and power generation facilities.

Emissions from waste incinerators are still a significant air pollution problem, despite advances in control technology. In order to control these pollutants, engineers must know the chemical makeup of the waste material. Studies in the Center for Thermodynamics and Molecular Science led to the publication last year of thermodynamic data for 331 selected materials important to waste incineration processes. The data provide engineers with information that will help them design facilities to handle waste materials in a more effective and environmentally acceptable manner. This publication also offers engineers better measurements of the potential energy content of the waste stream for use in projects to recover heat from the incineration process. Undertaken in conjunction with a committee of the American Society of Mechanical Engineers and administered through the NBS Office of Standard Reference Data, its inclusion in the Bureau-operated standard reference data network ensures its

NBS scientists are involved in determining rates of elementary reactions important in understanding the earth's atmosphere. One of the Bureau's postdoctoral research associates, David Shold (left), compares notes on one of these projects with his advisor, NBS chemist Pierre Ausloos.

widespread distribution and use as a carefully evaluated and accurate data source. (For more information about the National Standard Reference Data System, see page 67.)

The Bureau also focuses on what happens in the upper levels of the atmosphere. During FY 1978, NBS carried out basic research studies leading to a revision in previous estimates about possible damage to the earth's protective ozone layer posed by supersonic transport planes and by fluorocarbons from aerosol propellants and other sources. Because of the complex individual and chain interactions of various pollutants with each other and with naturally occurring concentrations of atmospheric constituents, it is necessary to determine many reaction rates in order to estimate how the addition of each pollutant would affect the present quality of our atmosphere. Using these reaction rates between pollutants and atmospheric constituents and between each other, the atmosphere can be accurately modeled or simulated. This model can then be utilized to estimate the effects of specific substances in the atmosphere.

In a joint program with the National Oceanic and Atmospheric Administration, NBS identifies and experimentally measures critical chemical reactions using advanced laser spectroscopic techniques developed at the Bureau. Scientists in the Bureau's Center for Absolute Physical Quantities last year reported on research to determine the reaction rates when hydroperoxyl radicals—important components of the upper atmosphere—interact with nitric oxide. The NBS-NOAA research involved the direct measurement of this chemical reaction for the first time. When this information was plugged into a computer model of the upper atmosphere, it significantly altered earlier analysis of the ozone depletion problem. Accordingly, supersonic transports are now judged to have little effect on the ozone layer. In fact, at some altitudes, they may actually create ozone. As a result of this research, however, damage to the ozone layer from fluorocarbons is estimated to be three times greater than had been previously assumed.

The latest basic data used as input by all models of stratospheric pollution effects were published in FY 1978 by the Bureau as part of the NBS program of standard reference data evaluation and dissemination. *Reaction Rate and Photochemical Data for Atmospheric Chemistry,* NBS Special Publication 513, is a compilation of over 400 critically evaluated reaction rate items. It was cosponsored by the Department of Transportation, the National Aeronautics and Space Administration and three NBS groups—the Office of Standard Reference Data, the Office of Environmental Measurements, and the Center for Thermodynamics and Molecular Science. Like most of the Bureau's environmental research and services, this publication provides the measurement necessities for monitoring, evaluating, and improving the quality of our environment.

Making More Effective Use of Computers

Ever since NBS developed one of the world's first stored program electronic computers about 30 years ago, the Bureau has been a source of expertise on computer use for the Federal Government. As Federal utilization of computers has grown, the scope of NBS activities has been broadened to include a technical and scientific role in the overall management of Federal automatic data processing (ADP) technology.

In 1965, Public Law 89-306 (Brooks Act) established the goal of economic and efficient purchase, lease, maintenance and operation, and use of ADP equipment by Federal departments and agencies. Under this Act, the NBS Institute for Computer Sciences and Technology (ICST) is responsible for developing and recommending computer standards for Federal use and for participating in the development of voluntary computer standards. ICST provides technical support for the formulation of Federal ADP management and procurement policies, the selection and direction of Federally-sponsored computer research and development, and the resolution of issues affecting computer utilization. ICST also helps other government agencies solve computer-related problems and conducts computer research needed for standards development and advisory services.

Standards Development

During the past year ICST completed a broad range of technical projects in computer standards, technical assistance, and computer science research. Recently developed computer stan-

NBS computer standards ensure that Federal agency computer users will be able to purchase equipment competitively from independent suppliers. In the Bureau's magnetic media laboratory, electronic engineer William Truitt calibrates flexible disks for use as Standard Reference Materials.

NBS provides other Federal agencies with technical advice to help improve their use of computers. Computer scientist Belkis Leong-Hong (top photo) studied the problems of Federal database administrators. The study will help NBS in developing standards for database management systems.

The Bureau is developing interface standards for computer networks which will improve user access to the resources of those networks. Below, in the NBS experimental computer facility are Robert Rosenthal, Shirley Ward Watkins, and Robert Blanc (left to right).

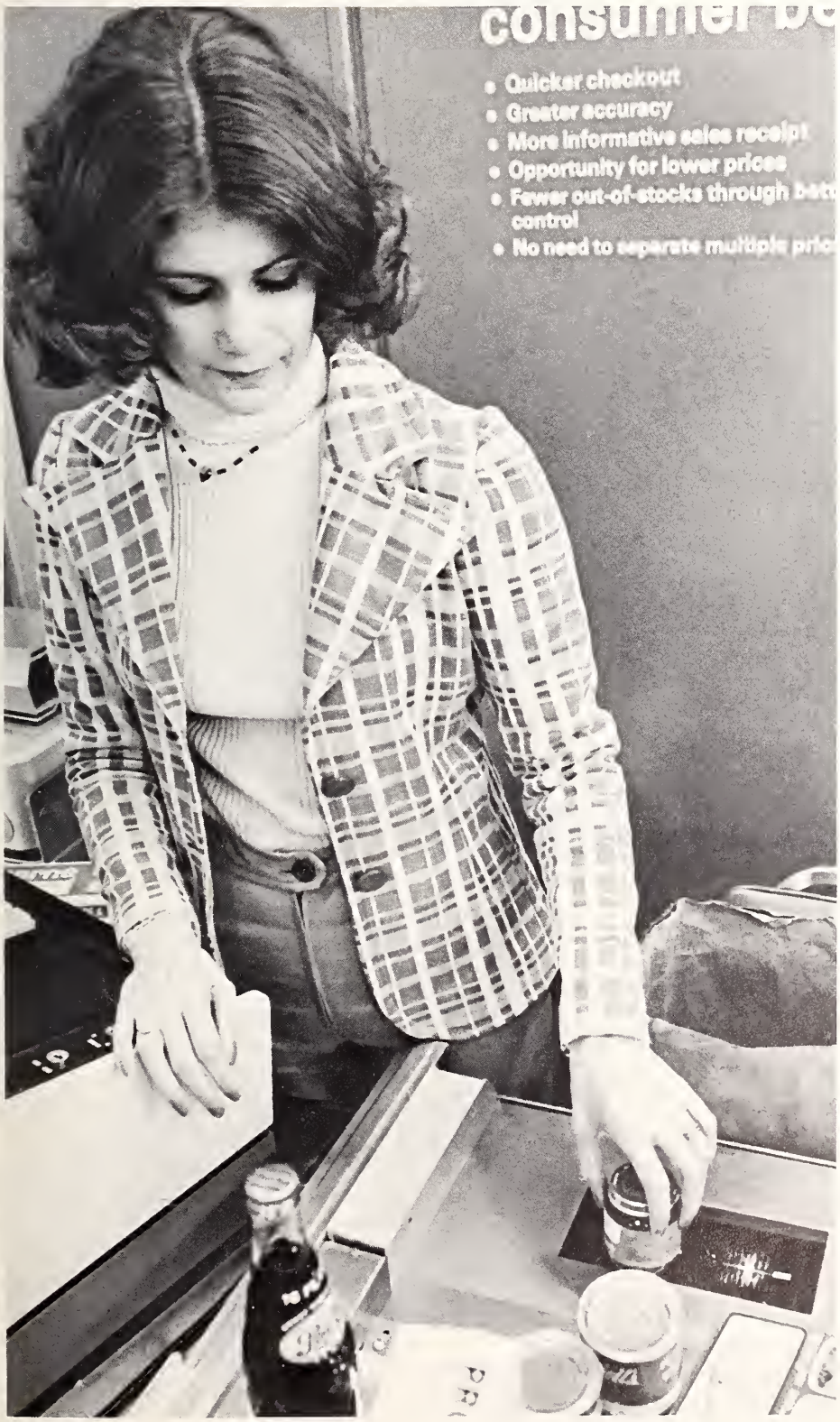
dards for Federal use, issued as Federal Information Processing Standards, include the following:

- standards for recorded magnetic tape, magnetic tape cassettes and cartridges to facilitate interchange of data recorded on magnetic media, and reproducing equipment used in Federal ADP systems;
- standard codes to identify more than 136,000 U.S. cities, towns, and places for use in the processing and exchange of information;
- standard sizes and formats for microforms to improve the handling of computerized data in microimage form;
- guidelines for evaluating the performance of interactive network systems;
- guidelines to help ADP managers solve problems that may arise in planning, acquiring, operating, and maintaining ADP systems composed of components from different vendors. These multivendor systems are expected to increase as computer system interface standards are issued.

Three standards for the input/output channel level interfaces of medium and large scale computer systems were proposed for Federal use and were disseminated for public review and comment. The standards will assure the proper interconnection of peripheral equipment, such as magnetic tape and disk equipment, to computer systems. This means that Federal agencies will be able to use fully competitive procurements when purchasing new magnetic tape and disk equipment, resulting in significant cost savings.

To keep pace with changing technology, ICST proposed a program of close industry-government cooperation in developing the technical foundation for future interface standards. Individual computer companies as well as trade

An explanation of some of the current and upcoming uses of computer technology in the supermarket, retail stores, and banking is offered in a new NBS pamphlet, ***Automation in the Marketplace.***



and professional associations were invited to work with ICST staff through the NBS Research Associate Program. The focus will be the computer systems, network architectures, and interconnection techniques that are likely to be in widespread use in the next 5 to 10 years.

Protection of the Federal Government's computers and the data they process from accidental or deliberate destruction, modification, or disclosure continued to receive emphasis at NBS. Studies covering a variety of approaches to system security were published: analysis of available safeguards for detecting and preventing intentional computer misuse, development of security controls in a computer network, and evaluation techniques to detect fraud and errors and to assure the accuracy of computer data. Work also continued on the development of test methods for evaluating equipment that controls individual access to computer systems through verification of personal characteristics such as voice, fingerprints, or hand shapes.

A major step to protect computer data that are transmitted between terminals and computers or between computers was taken in 1977 when NBS issued the Data Encryption Standard (DES). The DES provides for cryptographic techniques, carried out in computer hardware, to encode computer data before transmission and to decode it before use. A secret computer key is used to encode and decode the data.

Electronics manufacturers have now developed a variety of encryption devices for implementing the DES. Before these commercial devices can be sold to Federal agencies, however, they must be submitted to the ICST Data Encryption Validation Service for a series of tests. After successful completion of the tests—which compare the operation of the device to

The Bureau's computer expertise has been called upon by the FBI for aid in automating their fingerprint identification system. In an extension of this work, mathematician Joe Wegstein (left) and electronic engineer John Rafferty discuss a new method for reading latent scene-of-the-crime fingerprints.

the standard—a validation certificate can be issued to the manufacturer.

By the end of FY 1978, seven devices from six different manufacturers had been tested and validated. These devices may be imbedded in computer terminals, communications processors, cash issuing machines, and personal identification devices. ICST has also been developing standard protocols for transmitting encrypted data through a communications network.

Technical Assistance

ICST's technical assistance to other agencies involves aid in the selection, procurement, and application of computers. Such projects help the sponsoring agency make more effective use of computers and, at the same time, contribute to ICST's standards-making and research programs.

About 10 years ago, the Federal Bureau of Investigation asked NBS for help in automating its fingerprint identification system. In 1967 there were about 17 million fingerprint cards in the FBI arrest file. Today there are more than 21 million cards in the file, and four six-drawer file cabinets of records are added to the collection each day. As many as 30,000 requests for fingerprint identification are received daily.

NBS research efforts have been devoted to devising automated techniques for reading fingerprint data, organizing files, searching files, and matching fingerprint data. Computer programs and special devices have been developed to read the patterns created by fingerprints and to convert the characteristics of the patterns into computer data that can be compared to data in a fingerprint file. ICST is now helping the FBI prepare specifications and monitor the work of private contractors who are producing prototype and production models of equipment that will read and match fingerprints.

Special methods also have been developed recently for reading latent scene-of-the-crime fingerprints and matching them with rolled file fingerprints. Because of their poor quality, latent fingerprint characteristics are read by a fingerprint expert using a semi-automated reader. The data are then compared to the data read automatically from rolled prints by a special matcher. Techniques for automatic classification of fingerprints are also being explored.

Other projects completed in FY 1978 include:

- design of an advanced system of computerized security techniques to protect special military weapons and materials storage sites. Developed for the Defense Nuclear Agency, the system design provides a network of microprocessors linked with devices for detecting disturbances and also connected with a central processor. Warnings for security forces are

In developing computer security and risk management standards, NBS is testing devices which identify individuals seeking access to computer networks and the information they hold. Electronic engineer Paul Meissner is shown in the Bureau's personal identification laboratory with a signature identification device.

computer-generated based on input from the network.

- technical assistance to the National Commission on Libraries and Information Science in the development of a high-level networking protocol to improve information interchange between libraries.

- study of the legal, economic, and technical issues involved in extending copyright protection to computer-readable works. The study, sponsored by the National Science Foundation, recommended copyright protection for computer programs written in a source language and computer-readable data bases.

- an NBS consumer information pamphlet, entitled *Automation in the Marketplace,* that explains some of the current and upcoming uses of computer technology in the supermarket, retail stores, and banking. (Order information is provided on page 71.)

Plans for a Restructured Standards Program

Top-level government officials have stressed the important role that ADP technology plays in making government work more efficiently and effectively. As the world's largest ADP user, the Federal Government spends over $10 billion a year on ADP equipment and personnel and owns or leases more than 11,100 computers. Recent studies of Federal ADP activities by Congressional and Executive offices have reinforced the importance of standards in the effective management of ADP resources and the control of costs.

During the past year ICST developed a long-range plan to strengthen the government-wide computer standards program and to improve implementation of the Brooks Act. The plan was endorsed by the White House Office of Management and Budget and Congress approved funds to begin implementation in FY 1979.

The new program will concentrate on developing families of standards to help Federal users trim their ADP costs and improve the effectiveness of their computer systems. Standards for the interconnection of computer system components to promote the competitive procurement of components and systems, and standards for computer security and risk management procedures to protect computers and data are examples of these types of standards.

There will also be increased emphasis on standards for computer software, now a significant portion of overall ADP costs. These include: high-level programming language standards to reduce the costs of converting software from use on one manufacturer's system to another's; quality control standards to improve the reliability of software and to reduce the costs of maintaining it; and data base management standards to improve the effective use of files and to cut the costs of converting common data from one use to another.

As part of the 5-year plan, ICST will monitor changing technology and the costs, benefits, and impacts of standards to assure that planned standards activities continue to meet the needs of the Federal Government. And, it will continue to cooperate closely with the General Services Administration and the Office of Management and Budget to assist Federal agencies in the use of standards, to keep the program responsive to agency needs, and to survey agency compliance with standards.

Science and Technology Transfer: Services and Special Programs

NBS offers a broad range of services and opportunities for cooperative activity with Federal, State, and local governments, industry, universities, technical societies, voluntary standards groups, trade associations, international organizations, and the general public. Supplementing an informal, long-standing tradition of consultation with the public and private sectors, these efforts are designed to foster the transfer of science and technology from the Bureau to NBS users. Listed below are some of these services and programs, along with information about how to obtain additional details.

Calibration Services

By facilitating the calibration of instruments and devices, NBS helps accomplish a critical portion of its total mission: to provide the basis for a complete and consistent national system of physical measurements. The Bureau's calibration services cover: mass and dimensional metrology; mechanics and acoustics; electrical and magnetic measurements (dc and low frequency); electromagnetic measurements at radio, microwave, millimeter wave, and laser frequencies; time and frequency; thermodynamic quantities; optical measurements; and ionizing radiation. A complete description of these and related measurement services, several of which are also described below, is provided in *Calibration and Related Measurement Services of the National Bureau of Standards.* (Order information can be found on page 71.)

Engineer Jim Hill describes NBS solar energy research to a group of high school students as part of the Bureau's Science and Technology Enrichment Program, a community outreach effort in which NBS scientific and technical staff work with Washington-area public schools.

National Standard Reference Data System (NSRDS)

NSRDS was established in 1963 as a nationwide program designed to give scientists and engineers easy access to critically evaluated, reliable data. The program is coordinated by NBS, but involves many groups in universities, government laboratories, and private industry. NSRDS now has more than 50 data centers located at NBS and throughout the country which pull together the results from many diverse research activities around the world and organize these data into a more dependable and useful form. Further information, including lists of data centers, is available from the NBS Office of Standard Reference Data, Physics Building, Room A323, (301) 921-2467.

Standard Reference Materials (SRM's)

SRM's are well-characterized, homogeneous, stable materials or artifacts with specific properties measured and certified by NBS. They are widely used throughout the world in a variety of measurement applications, including the evaluation of the accuracy of test methods, improvement of measurement compatibility among different laboratories, and establishment of measurement traceability to NBS. Since the first SRM was issued in 1906, the Bureau has made available over 1,000 different SRM's. During FY 1978, NBS sold 37,000 SRM units to more than 10,000 users around the world. The program is operated by the NBS Office of Standard Reference Materials, Chemistry Building, Room B311, (301) 921-2045.

Measurement Assurance Programs (MAP's)

Over the past decade, NBS has developed a series of Measurement Assurance Programs (MAP's) to assist laboratories that wish to improve or verify their capabilities for making accurate measurements. Measurement assurance services provided by NBS allow public or private laboratories to test their entire measurement system, from people to equipment to basic methodologies, for accuracy and traceability to NBS. At present, NBS offers MAP's in areas including voltage, mass, resistance, laser power and energy, and several others. For more information, contact the NBS Office of Measurement Services, Physics Building, Room B362, (301) 921-2805.

Standards Information Service

The NBS Standards Information Service (NBS-SIS), operated by the Bureau's Office of Engineering Standards, maintains a comprehensive reference collection of engineering and related standards. The NBS-SIS collection includes over 240,000 standards, specifications, test methods, codes, and recommended practices issued by U.S. technical societies, professional organizations, trade associations, State purchasing offices, Federal agencies, and foreign national and international standards organizations. The collection also contains reference books, articles, reports, newsletters, and microfilm files. Free lists of standards compiled by NBS-SIS, together with names of organizations where copies of the standards can be obtained, are available. Requests

The NBS Research Associate Program enables technical specialists in U.S. firms and professional organizations to work at the Bureau temporarily to carry out projects of mutual interest. Chemist Marlene Morris of the International Centre for Diffraction Data is that group's liaison with NBS.

should be as specific as possible and addressed to the Standards Information Service, Technology Building, Room B162. Requests can also be made by telephone at (301) 921-2587 or by Telex 89-8493.

Energy-Related Inventions Evaluation

To ensure that all promising energy-related inventions receive a thorough and objective review—particularly inventions from individual inventors and small firms—the NBS Office of Energy-Related Inventions offers free evaluations. Established by the Federal Nonnuclear Energy Research and Development Act of 1974, the NBS program provides a way for anyone with a nonnuclear, energy-related invention to have a technical review of the device, material, process, and/or procedure. If the evaluation by NBS shows that an invention has significant promise for either saving or producing energy, NBS recommends it to the Department of Energy, which will consider providing the inventor with assistance to help develop the invention.

Last year, NBS received 3,437 requests for evaluations and recommended 35 inventions to DOE as especially promising. From mid-1975 when NBS opened its inventions evaluation office through September 30, 1978, the Bureau received a total of 9,697 requests for evaluations and recommended a total of 81 inventions to DOE. For more information and an evaluation request form, write to the NBS Office of Energy-Related Inventions, Polymers Building, Room A346, (301) 921-3694.

Research Associate Program

This program enables scientists and engineers from industrial, professional, trade, and other organizations to work at NBS for specified periods under the opportunity for cooperative research sponsorship of their employers on projects of clear mutual interest to the sponsor and NBS. The Research Associate Program offers industry an under the supervision of and in consultation with NBS professionals and makes available the use of the Bureau's extensive laboratories and related facilities. The program provides a means of communicating directly to NBS the views of industry on needs and problems requiring attention.

During FY 1978, more than 100 Research Associates worked with NBS on 30 different projects. Of these programs, 60 percent were sponsored by trade and professional organizations, with most of the remainder sponsored by private industrial companies. Since the program began in 1920, more than 400 organizations and 1,000 individuals have participated. For additional information, write or phone the Industrial Liaison Officer, Administration Building, Room A402, (301) 921-3591.

State and Local Liaison

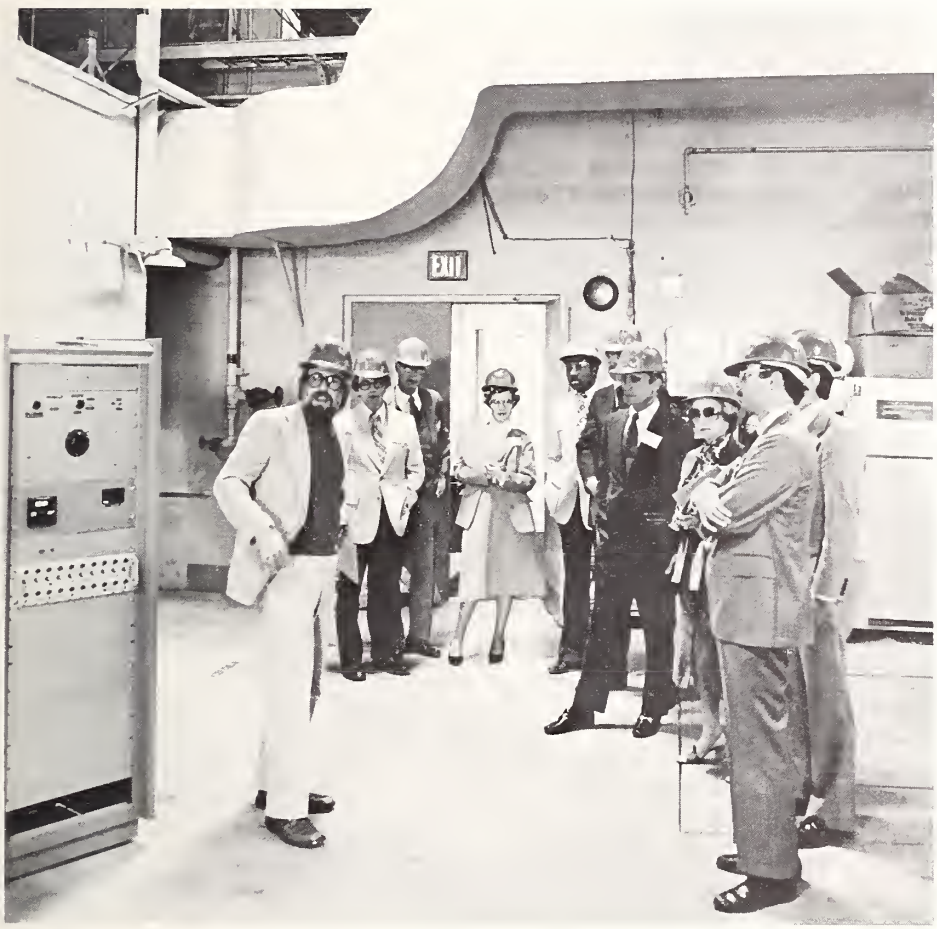
An important portion of NBS research activities addresses matters of substantial interest to State and local governments. Prime examples of this segment of the Bureau's efforts include equipment standards, weights and measures, and Standard Reference Materials. NBS seeks to make the results of its research readily available to State and local jurisdictions by maintaining contacts with national organizations and by a program of outreach to individual jurisdictions. These governments are also encouraged to contact NBS directly for information about areas of interest in which the Bureau is now working or may have been working in the past.

As part of its efforts to stay in close touch with the needs of States and localities, NBS participates in the Intergovernmental Personnel Exchange (IPE) program. IPE is a mechanism to bring employees from these jurisdictions and from universities to the Bureau in order to work with NBS staff on particular areas of joint interest. It also enables NBS employees to work for State and local governments. For more information about IPE or about any Bureau activity, State and local representatives should contact the NBS State and Local Government Liaison Officer, Administration Building, Room A402, (301) 921-3814.

Other Exchange Programs

In addition to the Research Associate and IPE programs, NBS offers several other opportunities for personnel exchange in order to bring researchers to the Bureau to work on specific projects and to provide better dissemination of NBS research directly into user communities. These include a Guest Worker program which permits specialists to work with NBS staff on projects of mutual interest for periods of several months to 2 years. Foreign institutions and governments, international organizations, or U.S. groups sponsoring the guest worker provide

Richard Custer of the Center for Fire Research explains the Bureau's extensive fire testing facilities to a group of radio and television broadcasters touring NBS. Several thousand visitors are conducted on special tours each year.



support for the NBS guests. Researchers from abroad seeking more information about this program should contact the NBS Office of International Relations, Administration Building, Room A511, (301) 921-2463. U.S. researchers should contact individual NBS divisions or centers directly.

The NBS Postdoctoral Research Associate Program provides opportunities to postdoctoral scientists and engineers of unusual promise and ability to conduct research on problems that are compatible with Bureau interests and thereby contribute to the overall NBS research effort. Operated in cooperation with the National Research Council, this program is intended to be analogous to fellowships, associateships, and similar temporary programs at the doctoral level in universities and other organizations. Further details about this program may be obtained from the Coordinator, Postdoctoral Research Associate Program, Materials Building, Room A355, (301) 921-2901.

Conferences, Tours, Exhibits, Films

As one of the world's crossroads for science and technology, NBS is a meeting place for the exchange of information and ideas. During FY 1978, the Bureau sponsored or cosponsored 70 major conferences with more than 18,000 participants. These meetings help channel the details of Bureau research to those who need this information. They also provide a forum for NBS professionals and other attendees to keep pace with the latest advances and needs in a wide range of science and technology areas.

Each year, the Bureau receives several thousand visitors who are conducted on special tours of NBS facilities. Last year, scientists, engineers, and other researchers, as well as government officials from the Soviet Union, South Korea, Venezuela, Japan, the People's Republic of China, and West Germany, were among the many international visitors to the Bureau. NBS also offers a general guided tour of its Gaithersburg, Maryland, facilities on a regular basis, and of its Boulder, Colorado, facilities by special arrangement. For tour information, write or call the Public Information Division, Administration Building, Room A633 (301) 921-2721 in Gaithersburg, or Program Information Office, Radio Building, Room 4001, 325 Broadway, Boulder, CO 80303, (303) 499-1000, ext. 3244.

Contact with Bureau activities and services is also provided through exhibits and films. During FY 1978, special exhibits explaining a variety of NBS activities were shown at 45 conferences, workshops, and other events, where they were viewed by more than 2 million people.

A variety of films describing specific activities are available to the public for free loan. During FY 1978, two new films were added to the Bureau's film library: "The Marketplace," which describes the role and importance of local weights and measures officials, and "Flashover: Point of No Return," which provides instructions about fire safety for health care personnel. For a film catalogue, write the NBS Technical Information and Publications Division, Administration Building, Room A617, or call (301) 921-2318.

The Bureau responded to nearly 65,000 requests for information from the general public last year. Information specialist Norma Redstone handles many of these requests by telephone.

General and Media Information

Last fiscal year, the Bureau received and responded to nearly 65,000 requests for information from the general public. These included requests for NBS publications, general and technical information about Bureau programs, and metric guides. Anyone wishing more detailed information on any aspect of NBS activities is encouraged to contact the NBS Technical Information and Publications Division, Administration Building, Room A617, (301) 921-2318.

The news media rely on NBS to provide the most accurate information on an array of subjects spanning every Bureau activity from time and frequency measurements to consumer product safety. In addition to providing support to all NBS programs and publishing the Bureau's general magazine, DIMENSIONS/NBS, the Media Liaison and General Publications Unit answers inquiries about NBS research from newspapers, magazines, radio, and television. More than 1,300 press queries were responded to last year. Members of the news media can contact the Media Liaison Office, Administration Building, Room A627, (301) 921-3181, for general information about the Bureau and specific details about NBS research. Information on the Bureau's Boulder facilities may be obtained by contacting the Program Information Office, Radio Building, Room 4001, 325 Broadway, Boulder, CO 80303, or by calling (303) 499-1000, ext. 3244.

Publications

NBS publications are among the most important conduits through which the Bureau shares the results of its research and studies with its many user audiences. Fifteen categories of publications, ranging from the Consumer Information Series to the *NBS Journal of Research* and technical handbooks and monographs, are issued. (Last year, NBS published in excess of 59,000 pages of research in the open literature.)

During FY 1978, more than 1,900 papers appeared in NBS publications and external journals. A selected list of Bureau publications issued during this period is provided below, along with several bibliographies. Unless otherwise stated, all publications are available at the price indicated from either the Superintendent of Documents, U.S. Government Printing Office (Supt. Docs.), Washington, DC 20402, or the National Technical Information Service (NTIS), Springfield, VA 22161, as noted. For foreign orders, there is a 25 percent mailing charge through Supt. Docs. and a $3.00 charge per document through NTIS. For a complete annual list of NBS publications, write Supt. Docs. for *Publications of the National Bureau of Standards,* NBS SP 305, Supplement 9, S/N003-003-01951-8, $7.50. The *NBS Publications Newsletter* provides a free, bimonthly listing of all Bureau publications with abstracts. To be placed on the mailing list for this document, write the Technical Information and Publications Division, National Bureau of Standards, Washington, DC 20234.

Timely reports of both technical and general interest on the work performed by NBS are available in the pages of DIMENSIONS/NBS, the Bureau's monthly magazine. A year's subscription is available from Supt. Docs. for $11.00.

Measurement Capabilities

Calibration and Related Measurement Services of the National Bureau of Standards (SP 250), B. C. Belanger, Editor. Supt. Docs. S/N003-003-01916-0, $3.00.

NBS Standard Reference Materials Catalog, 1979-80 Edition, Office of Standard Reference Materials, National Bureau of Standards, Washington, DC 20234, free.

From Sundials to Atomic Clocks: Understanding Time and Frequency (MN 155), James Jespersen and Jane Fitz-Randolph. Supt. Docs. S/N003-003-01650-1, $4.00.

National Standard Reference Data System Publication List (L.P. 81), Office of Standard Reference Data, National Bureau of Standards, Washington, DC 20234, free.

Public Health and Safety

Fire Research Publications (NBSIR 78-1504), 1977, Nora H. Jason, Editor. NTIS #PB284462, $3.50.

Reliability Basis of Load and Resistance Factors for Reinforced Concrete Design (BSS 110), Bruce Ellingwood. Supt. Docs. S/N003-003-01888-1, $2.75.

Properties and Interactions of Oral Structures and Restorative Materials (NBSIR 78-1573), James M. Cassel. NTIS #PB289913, $6.00.

Energy Resources

Energy-Related Publications (L.P. 78), JoAnne R. Debelius, Editor, Center for Building Technology, National Bureau of Standards, Washington, DC 20234, free.

Life-Cycle Costing: A Guide for Selecting Energy Conservation Projects for Public Buildings (BSS 113), Rosalie T. Ruegg, John S. McConnaughey, G. Thomas Sav, and Kimberly A. Hockenberry. Supt. Docs. S/N003-003-01980-1, $2.75.

Plan for the Development and Implementation of Standards for Solar Heating and Cooling Applications (NBSIR 78-1143A), David Waksman, James H. Pielert, Robert D. Dikkers, Elmer R. Streed, and William J. Niessing. NTIS #PB283237, $5.25.

Energy Management for Furnaces, Kilns, and Ovens (HB 124), Lawrence A. Wood, John F. Ward, and Kenneth G. Kreider. Supt. Docs. S/N003-003-01811-2, $1.60.

Better Materials Use

NDE Publications: 1972-1977 (NBSIR 78-1557), Leonard Mordfin, Editor. NTIS #PB289755, $4.50.

Corrosion Facts for the Consumer (CIS 9), Consumer Information Series, Jerome Kruger. Supt. Docs. S/N003-003-01947-0, 80 cents.

Economic Effects of Metallic Corrosion in the United States (SP 511-1), Lawrence H. Bennett, Jerome Kruger, et al. Supt. Docs. S/N003-003-01926-7, $2.30.

Materials for Fuel Cells (NBSIR 78-1472), Lawrence H. Bennett, Martin I. Cohen, et al. NTIS #PB285360, $7.25.

Solar Energy Systems—Survey of Materials Performance (NBSIR 77-1314), Leopold F. Skoda and Larry W. Masters. NTIS #PB273305, $6.50.

Industrial Productivity

Semiconductor Measurement Technology Publications List (L.P. 72) and *Semiconductor Technology Program Progress Briefs,* Electron Devices Division, National Bureau of Standards, Washington, DC 20234, free.

An Architecture for a Robot Hierarchical Control System (SP 500-23), Anthony Barbera. Supt. Docs. S/N003-003-01874-1, $4.25.

Subsidies, Capital Formation, and Technological Change: Summary and Conclusions (NBS GCR-ETIP 78-47), Charles River Associates, Inc. NTIS #PB285295, $6.50.

Environmental Quality

Reaction Rate and Photochemical Data for Atmospheric Chemistry-1977 (SP 513), Robert F. Hampson, Jr. and David Garvin, Editors. Supt. Docs. S/N003-003-01924-1, $2.75.

Workshop on Asbestos: Definitions and Measurement Methods (SP 506), C.C. Gravatt, Philip D. LaFleur, and Kurt F. J. Heinrich, Editors. Supt. Docs. S/N003-003-01993-3, $6.75.

Thermodynamic Data for Waste Incineration (NBSIR 78-1479), Eugene S. Domalski, William H. Evans, and Thomas L. Jobe, Jr. NTIS #PB284659, $8.00.

Computer Science

Automation in the Marketplace (CIS 10), Consumer Information Series, Shirley M. Radack and Grace G. Burns. Supt. Docs. S/N003-003-01969-1, 90 cents.

The Computer Science and Technology Series (L.P. 88) and *Computer Science and Technology Publications* (L.P. 84), Institute for Computer Sciences and Technology, National Bureau of Standards, Washington, DC 20234, free.

Performance Assurance and Data Integrity Practices (SP 500-24), Robert L. Patrick and Robert L. Blanc, Editors. Supt. Docs. S/N003-003-01879-1, $2.20.

Database Administration: Concepts, Tools, Experiences, and Problems (SP 500-28), Belkis Leong-Hong and Beatrice Marron. Supt. Docs. S/N003-003-01900-3, $2.20.

COBOL Instrumentation and Debugging: A Case Study (SP 500-26), Gordon Lyon. Supt. Docs. S/N003-003-01875-2, $1.40.

Miscellaneous

List of Voluntary Product Standards, Commercial Standards, and Simplified Practice Recommendations (L.P. 53), Standards Information Service, National Bureau of Standards, Washington, DC 20234, free.

List of NBS Handbooks (L.P. 56) and *NBS List of Monographs* (L.P. 48), Technical Information and Publications Division, National Bureau of Standards, Washington, DC 20234, free.

Publications and Services of the Cryogenics Division (TN 1005), National Bureau of Standards 1953-1977, D. J. Frizen and J. R. Mendenhall, Editors. Supt. Docs. S/N003-003-01920-8, $2.75.

Some References on Metric Information (L.C. 1070), Technical Information and Publications Division, National Bureau of Standards, Washington, DC 20234, free.

Consumer Product Technology Publications (L.P. 85), Center for Consumer Product Technology, National Bureau of Standards, Washington, DC 20234, free.

Funds and Facilities

In addition to the Gaithersburg site, NBS has a major laboratory in Boulder, Colorado.

To carry out its research and services, NBS operates modern physical facilities in two locations. In Gaithersburg, Maryland, located north of Washington, DC, NBS has 27 buildings in a campus-like setting on 230 hectares (575 acres). The Bureau also has 14 buildings on 83 hectares (208 acres) in Boulder, Colorado. The Joint Institute for Laboratory Astrophysics, cosponsored by NBS and the University of Colorado, is also located in Boulder. Here scientists carry out studies in atomic and molecular physics and astrophysics.

At Ft. Collins, Colorado, NBS radio stations WWV and WWVB broadcast standard time and frequency information. Another station, WWVH, broadcasts from Kauai, Hawaii.

As one of the Nation's largest physical science laboratories, the Bureau houses a number of special facilities and equipment. A high flux nuclear research reactor is used daily by scientists from NBS, other agencies, and universities in projects ranging from nuclear theory to analysis of food contaminants. An electron accelerator capable of producing well-focused electron beams of 140 million volts is used to produce high energy electrons, positrons, photons, and neutrons for nuclear research by NBS scientists and in cooperative studies with a number of university groups.

Another facility, the Synchrotron Ultraviolet Radiation Facility (SURF), is one of the few of its kind in North America. Having been converted into a storage ring, SURF is now capable of producing intense short wavelength ultraviolet radiation, which is especially useful for radiometry in studies of controlled nuclear fusion energy sources and atmospheric and space science programs.

Among other NBS facilities are a fire research laboratory, an experimental computer facility, and several environmental chambers. In addition, an extensive instrument shops division answers specialized research needs. Shop capabilities include glass blowing, optics, and metalworking.

Many of the Bureau's facilities are available for use by the scientific and engineering communities. These facilities are described more fully in *Special Technical Facilities at the National Bureau of Standards*. This 50-page booklet is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, and may be ordered by Stock No. 003-003-01601-2/1976 Ed., for $1.35.

The Bureau's budget for FY 1978 was $133.3 million. Direct Congressional appropriations accounted for about 53 percent of NBS funds, with an additional 41 percent resulting from work performed by NBS for other government agencies. The sale of NBS goods and services, such as Standard Reference Materials and calibrations, provided the final 6 percent. Support for Bureau programs from other agencies reflects NBS' role as a major physical sciences research laboratory for the entire Federal Government.

Total NBS Operating Funds — All Sources

(in millions of dollars)

	Fiscal 1978 (actual)	Fiscal 1979 (est.)*
Measurement Research and Standards	(62.1)	(67.9)
Physical and chemical measurements and standards	23.5	24.0
Materials and thermodynamics measurements and standards	22.6	24.3
Measurement assurance program	1.5	2.5
Applied measurement programs	14.5	17.1
Engineering Measurements & Standards	(58.2)	(62.6)
Engineering standards	2.5	2.8
Safety & engineering standards	18.2	19.0
Technical support to industrial productivity	27.8	30.2
Mathematical sciences	3.0	3.6
Fire science and engineering	6.7	7.0
Computer Sciences & Technology	(6.8)	(13.8)
Government-wide ADP standards	4.3	11.3
Scientific & technological advisory services	2.5	2.5
Cooperative Technology	(.6)	(1.9)
Central Technical Support	(1.5)	(4.5)
Competence programs		1.9
Central planning		.8
Postdoctoral research fellowship program	1.5	1.8
Capital Transfers and Facilities	(.8)	(1.5)
Facilities	.8	1.5
Non-technical Supporting Services for Other Agencies	(3.3)	(3.5)
Total NBS	**133.3**	**155.7**

*Includes pending pay raise supplemental of $2.7 million.

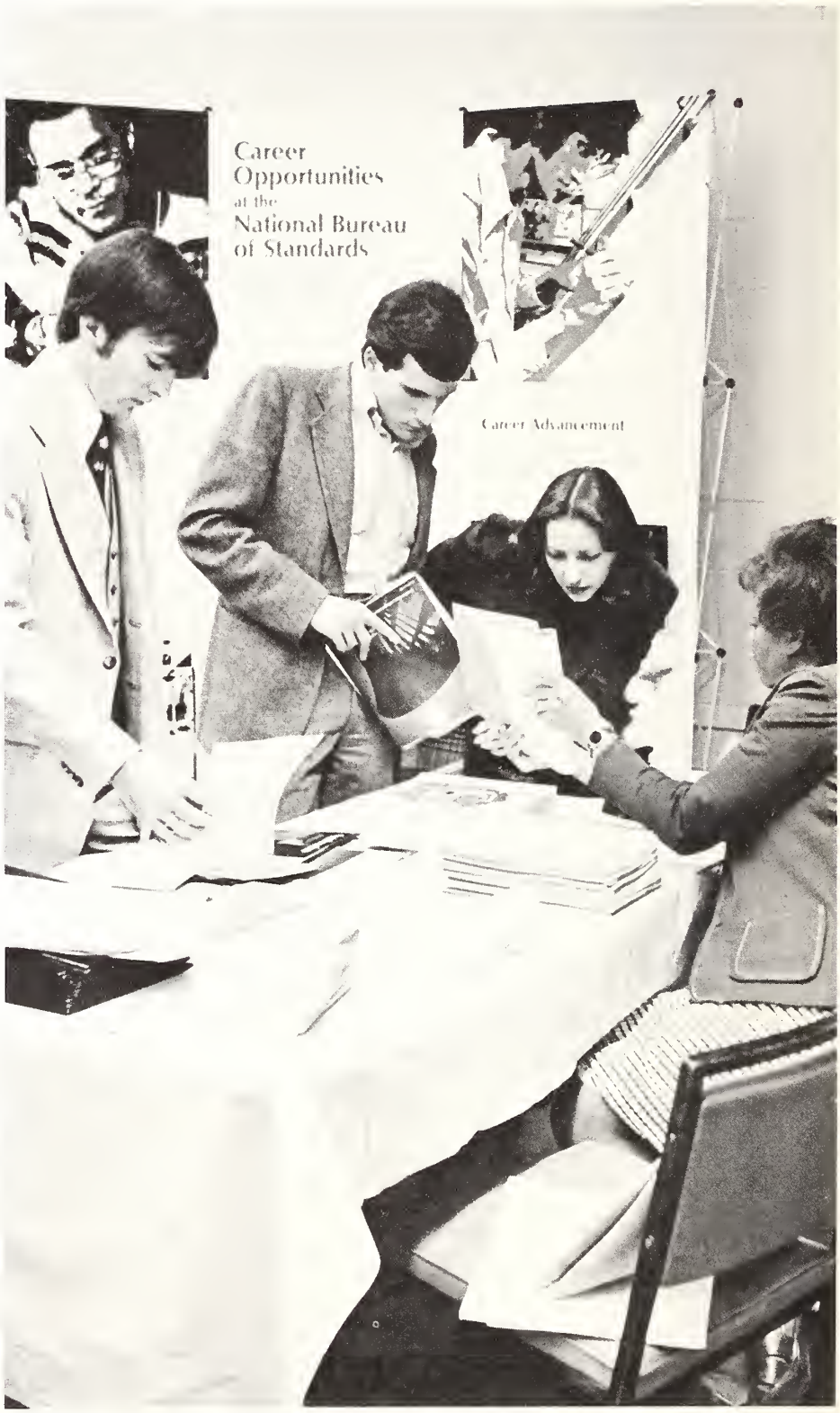
People

Guided by the NBS Executive Board and the Visiting Committee, the Bureau staff works to increase measurement competence and share its expertise with the scientific and technical community, industry, and the public.

The NBS Executive Board oversees the efforts of the entire Bureau staff. A series of evaluation panels appointed by the National Academy of Sciences (National Research Council) provides the Executive Board with valuable aid in these oversight functions. At the top of these evaluation and advisory functions is the NBS Visiting Committee, created by the NBS Organic Act and responsible for reporting annually to the Secretary of Commerce "upon the efficiency of its (NBS) scientific work and the condition of its equipment."

The staff has grown from its original team of 11 in 1901 to about 3,150 full-time employees. Approximately 2,750 are located in Gaithersburg, Maryland, with the remainder in Boulder, Colorado. The 1,225 Bureau physical scientists and engineers are complemented by 275 economists, architects, and other professionals. More than 44 percent of the research and scientific staff have earned doctorates. The research and scientific staff, the largest percentage of the NBS staff, is supported by almost 300 technicians, and by administrative, clerical, housekeeping, and groundskeeping personnel.

The contributions of NBS employees to the advancement of science and technology are often recognized by outside organizations. During the fiscal year, those staff members honored by independent and professional organizations included:



The Bureau's staff of 3,150 includes a large contingent of scientists and engineers in every specialization, along with professionals in a variety of other disciplines. Above, Ruth Bussie explains career opportunities at NBS to a group of university students in Washington, D.C.

Michael Baum of the Public Information Division received an award from the Washington, D.C. chapter of the Society for Technical Communication and an award from the Mid-Atlantic Chapter of the American Medical Writers Association for authoring outstanding periodical articles on NBS research.

John W. Cahn of the Center for Materials Science received the Acta Metallurgica Gold Medal, presented by the International Metallurgical Society for demonstrated ability and leadership in materials research.

William C. Cullen of the Office of Engineering Standards received the American Society of Testing and Materials 1978 Walter C. Voss Award for distinguished contributions to knowledge in the field of building technology.

Churchill Eisenhart of the Applied Mathematics Division was awarded the Samuel S. Wilks Memorial Medal for 1977 by the U.S. Army and the American Statistical Association for his contributions to the field of statistics.

Charles M. Eisenhauer of the Nuclear Radiation Division was elected a Fellow of the American Nuclear Society.

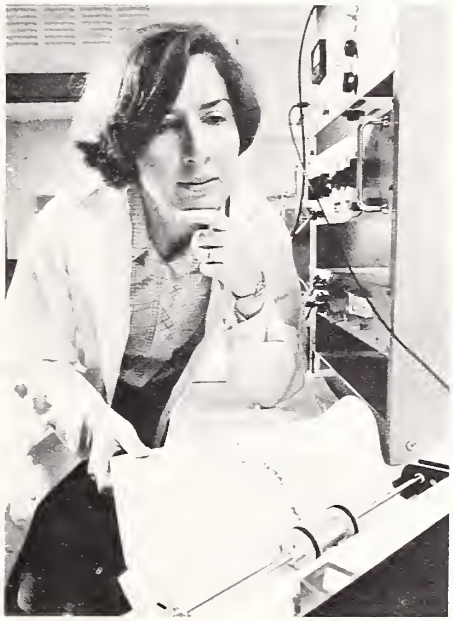
Ken Evenson of the Time and Frequency Division received the National Oceanic and Atmospheric Administration's Distinguished Authorship Award for coauthoring "Kinetics of the Reaction of HO_2 with NO."

Judson C. French, director of the Center for Electronics and Electrical Engineering, was elected a Fellow of the Institute of Electrical and Electronics Engineers.

Geoffrey Frohnsdorff, James Clifton, and Paul Brown of the Structures and Materials Division received the P. H. Bates Award given by the C-1 Committee of the American Society for Testing and Materials for the most outstanding paper in cement research developed in the previous 2 years.

J. William Gadzuk of the Surface Science Division was awarded a guest professorship by the Nordic Institute for Theoretical Atomic Physics to work at the Institute for Theoretical Physics, Chalmers University in Sweden.

Sandra Greer



Sandra C. Greer of the Thermophysics Division received the Annual Award for Scientific Achievement in the physical sciences for 1977 from the Washington Academy of Physical Sciences for her outstanding achievement as a research scientist in helping to produce a better understanding of the behavior of systems near critical points.

Kurt F. J. Heinrich of the Gas and Particulate Science Division received the 1978 Presidential Award from the Microbeam Analysis Society for his outstanding contributions to the theory and practice of microbeam analysis.

Robert J. Hocken of the Mechanical Processes Division was awarded the F. W. Taylor Medal of the International Institution of Production Engineering Research for a paper on a unique NBS three dimensional metrology machine.

Madeleine Jacobs of the Public Information Division received a total of six awards from the Washington, D.C. chapter of the Society for Technical Communication (STC), the International STC, and the National Association of Government Communicators for outstanding writing of news releases, periodical articles, and NBS' annual report.

Kurt F. Heinrich

Seymour Jeffery, chief of the Systems and Software Division, received a Certificate of Appreciation from the Institute of Electrical and Electronics Engineers Computer Society for distinguished service as Chairman of the Software Engineering Technical Committee.

David M. Kerns of the Electromagnetic Fields Division received the Institute of Electrical and Electronics Engineers Harry Diamond Memorial Award for outstanding technical contributions to microwave theory basic to power, impedance, and antenna standards and measurements.

F. Ralph Kotter of the Electrosystems Division received the IEEE Power Engineers Society Power System Instrumentation and Measurement Committee Distinguished Service Award.

Richard Kropschot, chief of the Thermophysical Properties Division, was elected a Fellow of the American Physical Society.

Howard P. Layer of the Length and Mass Measurements and Standards Division received one of *Industrial Research/Development* magazine's IR-100 awards for inventing a mini-stepping motor driver which increases the accuracy of the stepping motors commonly used in scientific equipment.

Paul S. Lederer of the Electrosystems Division was elected a Fellow of the Instrument Society of America.

E. P. Mabie, a research associate with the American Dental Association Health Foundation program in the Polymer Science and Standards Division, received a citation for meritorious service given by the Air Force Medical Center, Lackland Air Force Base.

Robert P. Madden of the Radiation Physics Division received the William F. Meggers Award of the American Optical Society for his contributions to ultraviolet spectroscopy.

Billy W. Mangum and Donald D. Thornton of the Temperature Measurements and Standards Division received one of *Industrial Research/Development* magazine's IR-100 awards for development of a highly accurate gallium melting-point reference in a part of the temperature scale where convenient references did not exist and where hospitals and clinics regularly make delicate and temperature-sensitive measurements.

Wilfrid P. Mann of the Center for Radiation Research was elected President of the International Committee for Radionuclide Metrology.

J. Franklin Mayo-Wells of the Electrosystems Division received the Instrument Society of America Distinguished Society-Service Award.

Robert E. Michaelis of the Office of Standard Reference Materials was elected an Honorary Member of the American Society for Testing and Materials, the society's highest honor.

James S. O'Connell, acting deputy director of the Center for Radiation Research, was elected a Fellow of the American Physical Society.

Elio Passaglia of the Center for Materials Science received an Award of Appreciation from the American Society for Testing and Materials Committee on Publication for outstanding service as an ASTM committee chairman.

Fredric E. Scire (left) and E. Clayton Teague

Frederic E. Scire and E. Clayton Teague of the Mechanical Processes Division received one of *Industrial Research/Development* magazine's IR-100 awards for designing a "Piezo-Flex" specimen stage for use in measuring very small dimensions with optical or electronic microscopes.

Collier Smith of the Program Information Office in Boulder received an award from the National Association of Government Communicators for outstanding writing of a news release.

Stephen J. Smith of the Quantum Physics Division received the Senior U.S. Scientist Award of the Alexander von Humboldt Foundation.

Jack L. Tech, chief of the Radiometric Physics Division, received a Service Citation Award of the Society of Photo-Optical Instrumentation Engineers.

John B. Wachtman, director of the Center for Materials Science, was elected president of the American Ceramic Society, serving a 1-year term beginning May 1978.

Sharon Washburn of the Public Information Division received an award from the National Association of Government Communicators for outstanding editing on the NBS annual report.

Sheldon M. Wiederhorn of the Fracture and Deformation Division received the Morey Award from the American Ceramic Society for outstanding research on the mechanical properties of glass.

John T. Yates of the Surface Science Division served on a 1-year appointment as a Sherman Fairchild Distinguished Scholar at the California Institute of Technology.

Department of Commerce Awards

Fifty-seven NBS staff members received Department of Commerce Gold, Silver, and Bronze Medal Awards for fiscal year 1978 work. The Gold Medal Award, the Department's highest employee honor, recognizes "rare and outstanding contributions of major significance to the Department, the Nation, or the world." The Silver Medal Award is the second highest honor and is presented for "contributions of unusual value to the Department." The Bronze Medal Award recognizes extremely competent performance of official duties in the Department of at least 5 years.

Gold Medal Award Recipients

Walter Braun of the Chemical Kinetics Division for outstanding contributions to modern gas kinetics through the development of flash photolysis resonance fluorescence and studies on laser augmented reactions.

Thomas D. Coyle, Chief of the Chemical Stability and Corrosion Division, for advances in measurement methods and understanding of inorganic synthesis and transformation and for applications in important fields of technology.

Judson C. French, Director of the Center for Electronics and Electrical Engineering, for unique and outstanding leadership of NBS solid-state electronics research and for exceptional management skills in developing the Semiconductor Technology Program.

Kurt F. J. Heinrich for his outstanding contributions to the Federal Government and to the Nation in advancing microanalysis techniques and applying them to problems of national significance.

Johanna M. H. Levelt Sengers of the Thermophysics Division for outstanding research on scaling and universality in the field of critical phenomena and its application to problems in engineering processes.

Silver Medal Award Recipients

Martin J. Aronoff of the Application Systems Division for exceptional leadership in the development of computer data services to support important national projects.

Daniel B. Butrymowicz of the Metal Science and Standards Division for developing expert reviews highly valuable to industry and science covering diffusion in metal alloy systems.

Burton H. Colvin, Director of the Center for Applied Mathematics, for distinguished contributions to the solution of national problems through the application of the mathematical sciences.

John R. Dise of the Office of Engineering Standards for outstanding contributions and leadership of the NBS Cement, Concrete, and Materials Reference Laboratories.

Joseph E. Fones in the Office of the Associate Director for Programs, Budget, and Finance for outstanding contributions to the fiscal and administrative management of the former Institute for Basic Standards.

James A. Grundl of the Nuclear Radiation Division for the development of standard neutron fields and measurement methods and their dissemination to the nuclear industry.

Johanna M.H. Levelt Sengers

Robert J. Hocken of the Mechanical Processes Division for outstanding technical contributions to accurate measurement of three dimensional objects.

Charles P. Howard of the Product Performance Engineering Division for outstanding skill in the development of energy test methods and efficiency targets for ten categories of appliances.

Clayton M. Huggett, Chief of the Office of Extramural Fire Research, for significant contributions in focusing public and private sector research on fundamental fire problems.

Frederick C. Johnson, Chief of the Mathematical Analysis Division, for improving the management of Pacific salmon fisheries through the development of mathematical modeling techniques.

George E. Kelley of the Building Thermal and Service Systems Division for developing rating procedures that encourage the design of energy-efficient heating and cooling equipment for homes.

Ernest G. Kessler, Jr., of the Center for Absolute Physical Quantities for outstanding contributions to measurement science by the establishment of improved standards in the gamma-ray region.

Neil T. Larsen of the Electromagnetic Technology Division for major innovations in microwave power standards and measuring instruments.

George P. Lewett, Chief of the Office of Energy-Related Inventions, for exemplary leadership in the design and implementation of the NBS Office of Energy-Related Inventions.

Sharon G. Lias of the Chemical Thermodynamics Division for outstanding contributions to the experimental and theoretical interpretations of the interactions of ions with matter.

Gordon E. Lyon of the Programming Sciences Division for original research and outstanding authorship in computer science.

Harold E. Marshall of the Building Economics and Regulatory Technology Division for outstanding leadership in developing and applying economics research to the solution of prominent national problems.

Taki Negas of the Ceramics, Glass, and Solid State Science Division for his work on the structural chemistry of complex oxides useful for their magnetic, electronic, and catalytic properties.

Arthur V. Phelps of the Quantum Physics Division for extraordinary achievement in transferring results of fundamental research to technological communities concerned with meeting national and industrial goals.

Darrell H. Reneker of the Polymer Science and Standards Division for his many important contributions to our understanding of the structure and properties of plastics.

Martin R. Shaver, Chief of the Computer Services Division, for outstanding leadership and contributions to the management and utilization of computing resources.

George A. Uriano, Deputy Chief of the Office of Standard Reference Materials, for outstanding contributions to the Standard Reference Materials Program in areas of health and industrial measurements.

James H. Winger of the Fire Safety Engineering Division for outstanding leadership in increasing public safety through the development of U.S. flammability standards.

J. Michael Rowe and John J. Rush of the Reactor Radiation Division for their outstanding contributions to the Federal Government and the Nation through creative research in metal-hydrogen systems in areas of national need.

Robert J. Celotta and Daniel T. Pierce of the Radiation Physics Division for the development of greatly improved sources, detectors, and measurement methods for spin-polarized electron beams.

P. Thomas Olsen and Edwin R. Williams of the Electrical Measurements and Standards Division for significantly advancing science and metrology through a high accuracy determination of the proton gyromagnetic ratio.

Robert P. Blanc, Robert Rosenthal, and Shirley W. Watkins of the Institute for Computer Sciences and Technology for the creation of a major new concept to significantly improve user access to computer networks and for the development and application of this concept so as to contribute to improved Federal computer utilization.

Bronze Medal Award Recipients

L. Kenneth Armstrong of the Office of the Director of Administrative and Information Systems for dedication, competence, and effective performance of duties in the professional and public relations of the National Bureau of Standards.

William H. Bailey of the Fire Safety Engineering Division for consistently outstanding support of fire research at the National Bureau of Standards.

Robert J. Boreni of the Ceramics, Glass, and Solid State Science Division for outstanding contributions to the design, construction, and use of the crystallographic data base.

E. Gail Crum of the Office of the Director of the National Engineering Laboratory for unusually competent performance of official duties over a prolonged period of time.

Jose E. Cruz of the Center for Electronics and Electrical Engineering for dedicated initiative and creativity in improving activities at the Boulder Laboratories.

Ronald D. Hunter of the Center for Electronics and Electrical Engineering for superior technical ability, effective management, and dedication to duty in support of electromagnetic measurement.

Donald C. Jensen of the Center for Information Systems for outstanding efforts to maximize the availability, cost effectiveness, and performance of the NBS central computer.

Elizabeth S. Kershow of the Center for Analytical Chemistry for superior performance of her official duties in the Center for Analytical Chemistry over a long period of time.

Elizabeth L. King of the Center for Absolute Physical Quantities for outstanding performance as secretary and administrative assistant to the Center for Absolute Physical Quantities.

Margery H. King of the Office of Cooperative Technology for excellent contributions as a Writer/Editor for the Director and as an expert member of the Programmatic Center for Cooperative Technology's Shoe Team.

Edgar H. MacArthur of the Office of the Comptroller for extraordinary competence in fulfilling the essential mission of ensuring a reliable financial system for NBS, NTIS, and NTIA.

Robert F. Martin of the Office of the Director of the National Measurement Laboratory for outstanding contributions to the fiscal and administrative management of the former Institute for Materials Research.

Harvey E. McCoy of the Center for Facilities Management in recognition of his outstanding performance in providing NBS with dependable and effective transportation services.

John L. Mills of the Radiation Physics Division for sustained and exceptionally competent performance of official duties in the NBS programs concerning measurements and applications of ionizing radiation.

Patricia A. Mullen of the Nuclear Radiation Division for sustained and exceptionally competent performance of official duties in the NBS radioactivity measurements program.

Edward P. Muth of the Center for Facilities Management for ingenuity, dedication, and leadership in extending optical fabrication techniques in support of scientific research.

Earl R. Pfeiffer of the Temperature Measurements and Standards Division for outstanding success in discharge of duties as Administrative Officer and technical aide to the Chief, Heat Division.

Carol A. Price of the Office of Engineering Standards for outstanding performance of duties and contributions beyond usual expectations as Secretary to the Director of the former Institute for Basic Standards.

Edwin B. Randall, Jr., of the Office of Engineering Standards for outstanding contributions to the National Bureau of Standards Collaborative Reference Programs.

Lucille E. Sithens of the Center for Information Systems for extraordinary competence and devotion to duty in ensuring a reliable financial system for NBS, NTIS, and NTIA.

Crittenden Awards

The Crittenden Award recognizes superior achievement by full-time, permanent employees who perform supporting services which have a significant impact on technical programs beyond their own offices. The award consists of a certificate and $500.

Carl R. Barry of the Center for Facilities Management in recognition of his extremely valuable contributions to the fabrication of complex scientific instruments for research efforts in the National Measurement Laboratory.

Ruby W. Brantley of the Center for Facilities Management in recognition of her continuing excellence and polite efficiency in the complex scheduling of conference facilities, equipment, and personnel at the National Bureau of Standards.

William J. Rice of the Center for Information Systems in recognition of his 35 years of capable, cheerful, and reliable service in the National Bureau of Standards Library and his strong support of the demands of technical and administrative programs.

Russell J. Rinehart of the Center for Facilities Management in recognition of his excellent support to the Bureau-wide activities of the scientific and administrative staff in the area of shipping and transportation.

Frank B. Saunders of the Center for Facilities Management in recognition of his effective, congenial, and dedicated service provided to the National Bureau of Standards and its staff as a valuable member of the Guard Force.

John P. Slusarz of the Center for Facilities Management in recognition of his expert purchasing guidance and his outstanding service in organizing improvements to the storeroom services of the National Bureau of Standards.

Charles K. Summers of the Center for Facilities Management in recognition of his economically valuable contributions in the fixture design and construction phase of the Liquefied Natural Gas tank measurement project.

Clyde C. Wachter of the Office of Standard Reference Materials in recognition of his valuable contributions to the Standard Reference Materials Program through his accurate and meticulous preparation, handling, and packaging procedures.

Stratton Award

The Stratton Award recognizes unusually significant research contributions to science or engineering in support of the National Bureau of Standards objectives which merit the acclaim of the scientific world. The award consists of a bronze plaque and $1,500.

Theodore E. Madey and John T. Yates, Jr., of the Surface Science Division for their many original research contributions in surface science, the sustained high quality and creativity of their work, and the significant practical benefits to catalyst chemistry.

Rosa Award

The Rosa Award recognizes outstanding achievements in the development of meaningful and significant standards of practice in the measurement field. The award consists of a brass plaque and $1,500.

Alexander F. Robertson of the Center for Fire Research for his outstanding leadership and participation in the United States voluntary standards system and his notable contributions to the advancement and development of standardization of flammability testing methods.

Condon Award

The Condon Award recognizes distinguished achievement in written exposition in science and technology. The award consists of an aluminum plaque and $1,000.

Roy G. Saltman of the Center for Programming Science and Technology for his scholarly report entitled, "Copyright in Computer-Readable Works: Policy Impacts of Technological Change," which has been highly acclaimed for its technical excellence.

Applied Research Award

The Applied Research Award recognizes superior achievement in the practical application of the results of scientific or engineering research. The award consists of a mixed metal plaque and $1,500.

Melvin Linzer of the Center for Materials Science in recognition of his development of a highly sensitive ultrasonic system—a major development embodying new technology, novel design, and theoretical approaches—immediately applicable to medical diagnosis and nondestructive evaluation of materials.

Equal Employment Opportunity Award

The Equal Employment Opportunity Award recognizes significant contributions to EEO which have been performed in an exceedingly outstanding manner by a Bureau employee. The award consists of an engraved plaque.

Melvin R. Wallace of the Center for Materials Science in recognition of his exceptionally significant and extremely effective service as the Equal Employment Opportunity Officer of the National Bureau of Standards.

Employees Honored by Major Federal Service Awards

The Presidential Recognition Program recognizes with a letter of commendation all employees who make exceptional contributions which reduce costs and conserve energy or significantly improve Government operations and services.

John W. Lyons, Director of the National Engineering Laboratory, in recognition of his unique and outstanding leadership in restructuring the diverse fire research activities at the National Bureau of Standards to support the development of the technology needed for solving the Nation's fire problem. A special certificate was presented to Dr. Lyons as part of the Presidential Management Improvement Awards Program.

Margie E. Kaszuba of the Center for Facilities Management in recognition of her outstanding day-to-day management of the mail and distribution activity at the National Bureau of Standards and the savings of nearly a quarter million dollars.

NBS Executive Board

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Dr. Thomas A. Dillon
Deputy Director

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Director
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Dr. John W. Lyons
Director
National Engineering Laboratory

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Director
Institute for Computer Sciences and Technology

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Director
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Associate Director for Programs, Budget, and Finance

*During FY 78, ICST Deputy Director M. Zane Thornton served on the NBS Executive Board.

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Department of Engineering-Economic Systems
Stanford University

Dr. Dorothy M. Simon
Vice President for Research
AVCO Corporation

Summary of Legislation

The Bureau's work is carried out under the founding "Organic Act" and a number of other U.S. laws. Summaries of some of the most important legislation authorizing NBS activities are provided below.

Highlights of the Organic Act of the National Bureau of Standards, 1901

15 U.S.C. 271

The Secretary of Commerce is authorized to undertake the following functions:

(a) The custody, maintenance, and development of the national standards of measurement, and the provision of means and methods for making measurements consistent with those standards, including the comparison of standards used in scientific investigations, engineering, manufacturing, commerce, and educational institutions with the standards adopted or recognized by the Government.

(b) The determination of physical constants and properties of materials when such data are of great importance to scientific or manufacturing interests and are not to be obtained of sufficient accuracy elsewhere.

(c) The development of methods for testing materials, mechanisms, and structures, and the testing of materials, supplies, and equipment, including items purchased for use of Government departments and independent establishments.

(d) Cooperation with other governmental agencies and with private organizations in the establishment of standard practices, incorporated in codes and specifications.

(e) Advisory service to Government agencies on scientific and technical problems.

(f) Invention and development of devices to serve special needs of the Government...

The Bureau is authorized to exercise its functions for the Government of the United States and for international organizations of which the United States is a member; for governments of friendly countries; for any State or municipal government within the United States; or for any scientific society, educational institution, firm, corporation, or individual within the United States or friendly countries engaged in manufacturing or other pursuits requiring the use of standards or standard measuring instruments: provided, that the exercise of these functions for international organizations, governments of friendly countries and scientific societies, educational institutions, firms, corporations, or individuals therein shall be in coordination with other agencies of the United States Government, in particular, the Department of State in respect to foreign entities.

Standard Reference Data Act, 1968

15 U.S.C. 290

The Congress hereby finds and declares that reliable standardized scientific and technical reference data are of vital importance to the progress of the Nation's science and technology. It is therefore the policy of the Congress to make critically evaluated reference data readily available to scientists, engineers, and the general public. It is the purpose of this Act to strengthen and enhance this policy.

The Secretary is authorized and directed to provide or arrange for the collection, compilation, critical evaluation, publication, and dissemination of standard reference data. In carrying out this program, the Secretary shall, to the maximum extent practicable, utilize the reference data services and facilities of other agencies and instrumentalities of the Federal Government and of State and local governments, persons, firms, institutions, and associations, with their consent and in such a manner as to avoid duplication of those services and facilities. All agencies and instrumentalities of the Federal Government are encouraged to exercise their duties and functions in such manner as will assist in carrying out the purpose of this Act. This section shall be deemed complementary to existing authority, and nothing herein is intended to repeal, supersede, or diminish existing authority or responsibility of any agency or instrumentality of the Federal Government.

The Congress included in the National Standard Reference Data Act Amendments of 1978 (P.L. 95-322) an amendment to the NBS Organic Act which, in effect, provides for periodic reauthorization of NBS programs and activities. The first such reauthorization will be required for fiscal year 1981.

Federal Fire Prevention and Control Act of 1974

15 U.S.C. 2201, Public Law 93-498

There is hereby established within the Department of Commerce a Fire Research Center which shall have the mission of performing and supporting research on all aspects of fire with the aim of providing scientific and technical knowledge applicable to the prevention and control of fires. In implementing this section, the Secretary is authorized to conduct, directly or through contracts or grants, a fire research program including:

(1) basic and applied fire research for the purpose of arriving at an understanding of the fundamental processes underlying all aspects of fire,

(2) research into the biological, physiological, and psychological factors affecting human victims of fire, and the performance of individual members of fire services, and

(3) operation tests, demonstration projects, and fire investigations in support of the activities set forth in this section.

The Secretary shall ensure that the results and advances arising from the work of the research program are disseminated broadly. He shall encourage the incorporation, to the extent applicable and practicable, of such results and advances in building codes, fire codes, and other relevant codes, test methods, fire service operations and training, and standards. The Secretary is authorized to encourage and assist in the development and adoption of uniform codes, test methods, and standards aimed at reducing fire losses and costs of fire protection.

The Federal Fire Protection and Control Act Amendments of 1978 amended the Organic Act to include "methods, procedures, and equipment for arson prevention, detection, and investigation."

Brooks Act, 1965

Public Law 89-306

The Secretary of Commerce is authorized:

(1) to provide agencies, and the Administrator of General Services with scientific and technological advisory services relating to automatic data processing and related systems, and

(2) to make appropriate recommendations to the President relating to the establishment of uniform Federal automatic data processing standards. The Secretary is authorized to undertake the necessary research in the sciences and technologies of automatic data processing computer and related systems.

Fair Packaging and Labeling Act, 1966

15 U.S.C. 1454

Informed consumers are essential to the fair and efficient functioning of a free market economy. Packages and their labels should enable customers to obtain accurate information as to the quantity of the contents and should facilitate value comparisons. Therefore, it is hereby declared to be the policy of the Congress to assist consumers and manufacturers in reaching these goals in the marketing of consumer goods.

Whenever the Secretary of Commerce determines that there is undue proliferation of the weights, measures, or quantities in which any consumer commodity or reasonably comparable consumer commodities are being distributed in packages for sale at retail and such undue proliferation impairs the reasonable ability of consumers to make value comparisons with respect to such consumer commodity or commodities, he shall request manufacturers, packers, and distributors of the commodity or commodities to participate in the development of a voluntary product standard for such commodity or commodities under the procedures for the development of voluntary product standards established by the Secretary pursuant to section 2 of the Act of March 3, 1901 (31 Stat. 1449, as amended; 15 U.S.C. 272). Such procedures shall provide adequate manufacturer, packer, distributor, and consumer representation.

If (1) after one year after the date on which the Secretary of Commerce first makes the request of manufacturers, packers, and distributors to participate in the development of a voluntary product standard as provided in subsection (d), or (2) if such a standard is published and the Secretary of Commerce determines that it has not been observed, he shall promptly report such determination to the Congress with a statement of the efforts that have been made under the voluntary standards program and his recommendation as to whether Congress should enact legislation providing regulatory authority to deal with the situation in question.

Resource Conservation and Recovery Act of 1976

Public Law 94-580

This Act establishes in the Environmental Protection Agency, an Office of Solid Waste to provide technical and financial assistance to State and regional agencies and to utilize information, facilities, personnel, and other resources of Federal agencies, including the National Bureau of Standards and the Census Bureau, on reimbursable basis, to perform research and analyses and conduct studies and investigations related to resource recovery and conservation and to otherwise carry out the Administrator's functions under this Act.

The Secretary of Commerce, acting through the National Bureau of Standards, and in conjunction with national standards-setting organizations in resource recovery, shall, after public hearings...publish guidelines for the development of specifications for the classification of materials recovered from waste which were destined for disposal. The specifications shall pertain to the physical and chemical properties and characteristics of such materials with regard to their use in replacing virgin materials in various industrial, commercial, and governmental uses. In establishing such guidelines, the Secretary shall also, to the extent feasible, provide such information as may be necessary to assist Federal agencies with procurement of items containing recovered materials. The Secretary shall continue to cooperate with national standards-setting organizations, as may be necessary, to encourage the publication, promulgation, and updating of standards for recovered materials and for the use of recovered materials in various industrial, commercial, and governmental uses.

Federal Nonnuclear Energy Research and Development Act of 1974

Public Law 93-574, Sec. 14

The National Bureau of Standards shall give particular attention to the evaluation of all promising energy-related inventions, particularly those submitted by individual inventors and small companies for the purpose of obtaining direct grants from the Administrator of the Energy Research and Development Administration (which is now part of the U.S. Department of Energy). The National Bureau of Standards is authorized to promulgate regulations in the furtherance of this section.

Solar Heating and Cooling Demonstration Act of 1974

42 U.S.C. 5501

Under various sections of the Act, NBS shall assist the Department of Housing and Urban Development (HUD) in determining interim performance criteria for solar heating and combined solar heating and cooling components and systems to be used in residential dwellings and interim performance criteria (relating to suitability for solar heating and cooling) for such dwellings themselves. NBS shall also work with HUD to establish test procedures and definitive performance criteria for solar heating and cooling components and systems and suitable dwellings. In addition, NBS is to aid in monitoring and evaluating the performance and operation of solar heating and combined solar heating and cooling systems installed in residential dwellings under the Act.

Energy Policy and Conservation Act, 1975

Public Law 94-163

This Act provides for an energy conservation program for consumer products other than automobiles. The Act states that the Administrator of the Federal Energy Administration (now part of the U.S. Department of Energy) shall direct NBS to develop test procedures for determination of (A) estimated annual operating costs...(B) at least one other useful measure of energy consumption of such products which FEA determines is likely to assist consumers...

In addition, the Act encourages the recycling of used oil and promotes the use of recycled oil. NBS shall develop test procedure for the determination of substantial equivalency of re-refined or otherwise processed used oil and new oil or additives with new oil for a particular end use. As soon as practicable after development of such test procedure, NBS shall report such procedure to the Federal Trade Commission.

Energy Conservation and Production Act, 1976

Public Law 94-385

This 1976 Act amends the Energy Policy and Conservation Act providing that FEA shall direct NBS to develop energy efficiency improvement targets for major energy-consuming household products. The Act requires the Department of Housing and Urban Development in consultation with FEA, Commerce, NBS, and GSA to develop and promulgate performance standards for new commercial and residential buildings within three years.

National Energy Conservation Policy Act, 1978

Public Law 95-619

These multiple laws provide for the direct and indirect involvement of NBS in a number of areas. The Bureau, along with several other agencies, is called upon to assist the Department of Energy (DOE) in the development of rules describing appropriate residential energy conservation measures in State residential energy conservation plans for regulated utilities. Provisions in previous energy statutes regarding appliance energy efficiency are amended and mandatory efficiency standards are authorized.

Provisions for improving the energy efficiency of industrial equipment state that DOE may direct NBS to assist in the development of test procedures for such equipment. Several provisions regarding energy conservation and solar energy programs for Federal buildings require DOE to consult with NBS in the development of life-cycle costing procedures and methodology and to assist in the development of energy efficient targets for Federal buildings. NBS is also cited to provide consultation to DOE in a study of the usefulness of the second law of thermodynamics in assessing the efficiency of certain energy uses.

Consumer Product Safety Act, 1972

15 U.S.C. 2056

This law directs the Consumer Product Safety Commission to "utilize the resources and facilities of the National Bureau of Standards...to perform research and analyses related to risks of injury associated with consumer products, develop test methods, conduct studies and investigations, and provide technical advice and assistance...'

Noise Control Act of 1972

42 U.S.C. 4907

This Act authorizes the Environmental Protection Agency to develop improved methods and standards for measuring and monitoring noise in cooperation with the National Bureau of Standards.

Metric Conversion Act of 1975

Public Law 94-168

This law provides for "Consultation by the Secretary of Commerce with the National Conference on Weights and Measures in order to assure that State and local weights and measures officials are appropriately involved in metric conversion and assisted in their efforts to bring about timely amendments to laws...Financial and administrative services...needed by the Board, may be obtained by the Board from the Secretary of Commerce..."

Earthquake Hazards Reduction Act of 1977

Public Law 95-124

The Act directs the President to establish and maintain a coordinated earthquake hazards reduction program. This program should provide for development of technologically and economically feasible design and construction methods and procedures, a system for predicting damaging earthquakes, and coordination of information about seismic risks with land-use policy decisions and building activities. NBS is among the agencies to be relied upon in carrying out this Act.

Directory

NBS technical work is carried out in the National Measurement Laboratory, the National Engineering Laboratory, and the Institute for Computer Sciences and Technology. These groups are supported by the Office of the Director of Administrative and Information Systems; the Office of the Director, NBS/Boulder Laboratories; and the Office of the Associate Director for Programs, Budget, and Finance. This amalgam of people and programs forms a community dedicated to service. The interdisciplinary approach allows NBS to provide the Nation with scientific measurements of high precision and accuracy, coupled with solutions for current and future technological problems.

This report has only highlighted some of the Bureau's programs. For more information on specific projects contact the people listed in this directory. To reach members of the Gaithersburg, MD, staff, dial (301) 921 + extension or write to the National Bureau of Standards, Washington, DC 20234. Bureau staff located in Boulder, CO, can be contacted on (303) 499-1000 and ask for the extension noted in the directory, or write to the National Bureau of Standards, Boulder, CO 80303. Boulder staff members are designated in the directory with asterisks.

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Mrs. Ana B. Jankowski, Equal Employment Opportunity Program Coordinator (2385)

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Office of the Associate Director for Programs, Budget, and Finance

The Office of the Associate Director for Programs, Budget, and Finance plans, develops, and evaluates Bureau-level programs and formulates and carries out policies and strategies for programmatic, budgetary, and financial matters. It develops techniques for and coordinates the review of technical and overhead programs; serves as the NBS Director's staff for Bureau-level programmatic, budget formulation and execution, and finance matters; and develops and maintains mechanisms to monitor planned and actual uses of resources by providing integrated, evaluated information on program progress, opportunities, and resources to the NBS Director. In addition, the Office advises management on significant changes and deviations and recommends program, budget, finance, and accounting priorities to the NBS Director.

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Mr. Thomas A. Gary, Chief, Budget Office (2544)

Mr. Larry D. Stout, Comptroller, Office of the Comptroller (2507)

Dr. Kenneth Gordon, Acting Director, Planning Office (3872)

Office of the Director of Administrative and Information Systems

The Office of the Director of Administrative and Information Systems directs the management of Bureau-wide facilities and information and administrative systems including information and office services, procurement, technical and public information functions, Bureau-wide computing, personnel, and management consulting services, health, safety, and security functions, as well as physical plant, facilities, space management, and instruments shops functions. The Office also decides on policies and plans and directs implementation actions to assure the responsiveness of these services to the needs of the technical programs.

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Mr. Clarence Hardy, Chief, Personnel Division (3555)

Mr. Richard de la Menardiere, Chief, Office Management Division (2113)

Boulder Executive Office

Mr. Arthur R. Hauler, Executive Officer (3955)*

Vacant, Chief, Instrument Shops Division (3855)*

Mr. Robert L. Rodger, Chief, Plant Division (3886)*

Office of the Director, NBS/Boulder Laboratories

The Office of the Director, NBS/Boulder Laboratories, which is located in Boulder, CO, provides support to the technical programs of the NBS/Boulder Laboratories. These laboratories conduct research comprising work on measurement science for the National Measurement Laboratory in time and frequency, quantum physics, thermodynamics, and materials science. The laboratories also carry out programs for the National Engineering Laboratory in electromagnetics, thermophysical properties, and fluid dynamics.

Mr. Bascom W. Birmingham, Director (3237)*

National Measurement Laboratory

The National Measurement Laboratory provides the national system of physical, chemical, and materials measurement; coordinates the system with measurement systems of other nations; and furnishes essential services leading to accurate and uniform physical and chemical measurement throughout the Nation's scientific community, industry, and commerce. It conducts materials research leading to improved methods of measurement, standards, and data on the properties of materials needed by industry, commerce, educational institutions, and government. NML also furnishes advisory and research services to other government agencies; conducts physical and chemical research; develops, produces, and distributes Standard Reference Materials; and provides standard reference data and calibration services.

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Institute for Computer Sciences and Technology

The Institute for Computer Sciences and Technology develops computer standards, conducts research, and provides scientific and technical services to aid Federal agencies in the selection, acquisition, application, and use of computer technology to improve effectiveness and economy in government operations in accordance with Public Law 89-306, relevant Executive Orders, and other directives. ICST manages a government-wide program for standards development and use, including management of Federal participation in ADP voluntary standardization activities. In addition, ICST provides technical support in: the development of Federal ADP management and procurement policies, the selection and direction of Federally sponsored computer research and development, and the resolution of computer utilization issues.

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Mr. Thomas N. Pyke, Jr., Acting Chief, System Components Division (3436)

National Engineering Laboratory

The National Engineering Laboratory furnishes technology and technical services to users in the public and private sectors to address national needs and to solve national problems in the public interest. NEL conducts research in engineering and applied science in support of objectives in these efforts; builds and maintains competence in the necessary disciplines required to carry out this research and technical service; and develops engineering data and measurement capabilities. NEL also provides engineering measurement traceability services; develops test methods and proposes engineering standards and code changes; develops and proposes new engineering practices; develops and improves mechanisms to transfer results of its research to the ultimate user; and develops and demonstrates new institutional practices to stimulate the use of technology.

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National Bureau of Standards