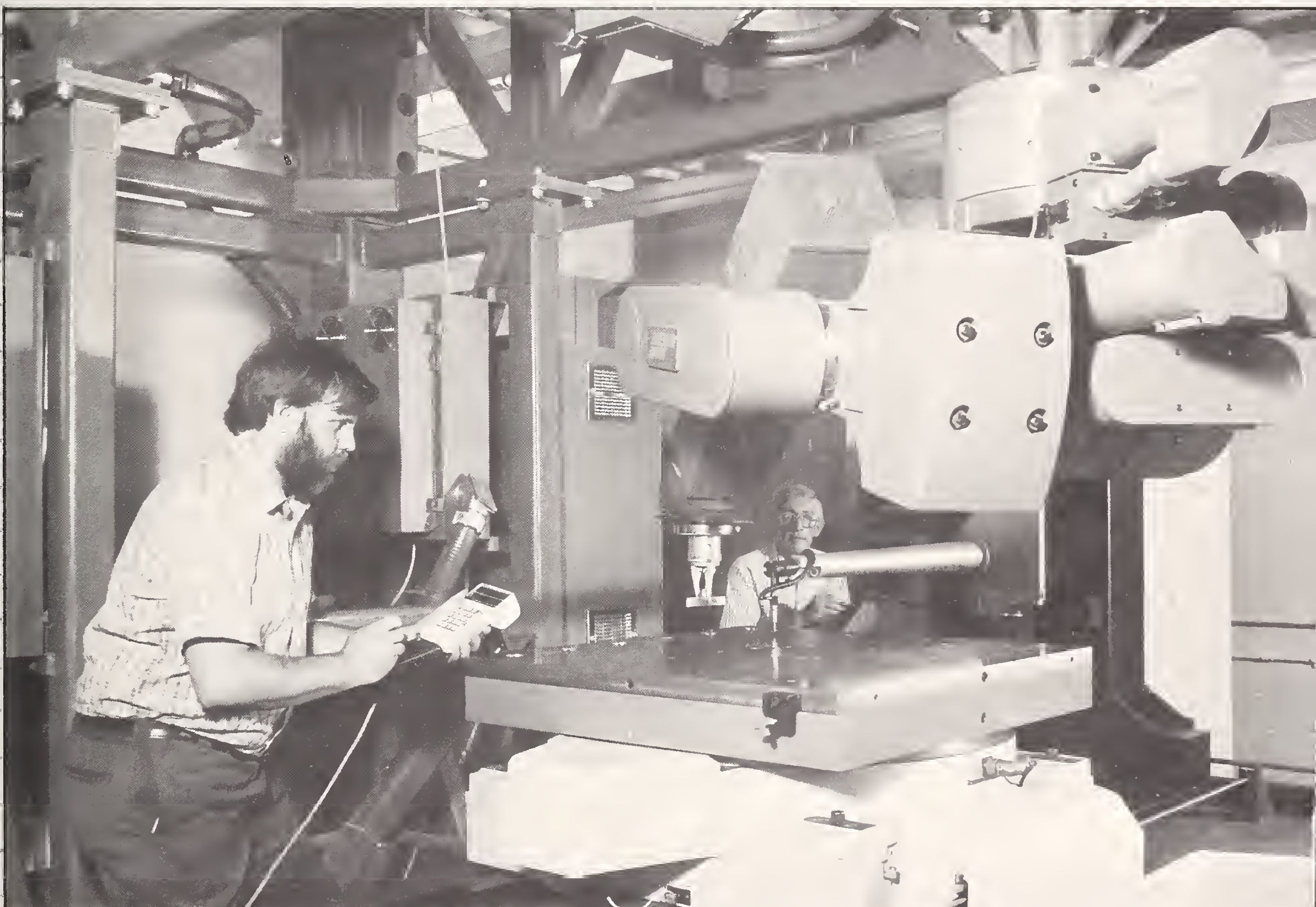
NATIONAL BUREAU OF STANDARDS

NBS Research Reports



U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
NBS SPECIAL PUBLICATION 680-1

Cover photo: This Automatic Inspection Workstation will be the final stop for parts made in the AMRF. Metrologists Bruce Borchardt (foreground) and Ralph Veale are "teaching" working positions to the robot that tends the coordinate measuring machine (CMM) in this workstation. When the AMRF is fully operational, this "teaching" step will not be necessary. **See page 6.**

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Focus on Cooperation and Communication: An Introduction

Reliable measurements are fundamental to growth and development in industry, to the advancement of science, and to equity in commerce. Consequently, the measurement science and technology work of the National Bureau of Standards relates directly to every segment of this society. NBS is, in fact, unique among national laboratories in serving such a broad clientele.

Today's National Science Policy is based on the premise that the public investment in federal science and technology should yield maximum public benefit. The President's Science Advisor, the Panel of the White House Science Council on Federal Laboratories, and the Congress all emphasize the importance of cooperation between the national laboratories and the potential users of federal science and technology in government, the universities, and industry. In particular, the 1980 Stevenson-Wydler Technology Innovation Act calls for improved communications by the national laboratories to stimulate such cooperation.

NBS works today, as it has for more than 80 years, to achieve these goals of involvement and outreach. For instance, each year more than 500 researchers from outside the Bureau—from universities, private companies, and other areas of government—work in NBS laboratories alongside Bureau staff members. Before this year is out, 15,000 individuals from around the country and abroad will journey to Gaithersburg, Md., or Boulder, Colo., to attend one of our technical conferences or workshops. Another 6,500 people will tour our laboratories.

We send our staff members to technical meetings and conferences. We produce about 200 publications each year—available from the Government Printing Office or the National Technical Information Service. Our researchers contribute well over 1,000 papers to the scientific literature. And some 470 of our staff participate in domestic or international standards-making bodies.

NBS Research Reports is our newest mode of communication. It looks at a number of Bureau programs in some detail—to give to managers and policymakers, as well as researchers and interested observers, a broader perspective on how NBS functions to benefit American science and industry.

We hope this publication will stimulate interest in NBS activities overall, a first step in strengthening the partnerships that in turn strengthen the nation's scientific base, its public services, and its industrial economy.

Ernest Ambler
Director

RESEARCH UPDATE

RESEARCHERS PATENT IMPROVED ACOUSTIC FLOWMETER

Two NBS physicists have received a patent on a device that uses long-wavelength sound waves to measure the rate of flow of a fluid in a pipe or duct. According to inventors James Potzick and Dr. Baldwin Robertson, the long-wavelength acoustic flowmeter represents an important improvement on earlier acoustic flowmeters that used ultrasonic sound waves because it can be used to measure the flowrate of gases—a fact confirmed by extensive experiments at NBS—and because it makes accurate measurements even when the temperature and velocity profiles of the gas fluctuate.

Potzick and Robertson's flowmeter design was received with considerable interest by private industry when the inventors applied for a patent in 1981. Two firms already have expressed interest in manufacturing a commercial version of the flowmeter. The Potzick-Robertson long-wavelength acoustic flowmeter was awarded patent number 4,445,389. Patent licensing is handled by the National Technical Information Service. For further information on the patent, contact George Kudravetz, Office of Government Inventions and Patents, NTIS, P.O. Box 1423, Springfield, VA 22151, 703/487-4732.

AIDS FOR MEASURING TOXIC METALS IN HUMAN URINE

NBS has developed a Standard Reference Material (SRM) that should improve measurements made when human exposure to a variety of toxic substances is monitored. Urine tests have been shown to be good indicators of exposure to toxic elements such as arsenic, mercury, and lead. For indications of long-term exposure to toxins, medical professionals normally rely on blood tests, but for an accurate gauge of short-term exposure, urine analysis usually is the method of choice.

The urine reference material (SRM 2670) is in powdered, freeze-dried form. Four bottles are included in the SRM: two each at low and elevated toxin levels. Included at both low and elevated levels are arsenic, cadmium, calcium, chloride, chromium, copper, lead, magnesium, manganese, mercury, nickel, potassium, selenium, sodium, and sulfate. For more information, contact: Office of Standard Reference Materials, B311 Chemistry Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2045.

IBM STAFFER JOINS NBS TO STUDY EMI PROBLEMS

The IBM Corporation, as a member of the Computer and Business Equipment Manufacturer's Association, has joined with NBS to study electromagnetic interference (EMI) with data processing and electronic office equipment. Robert F. German of IBM will spend a year or more as a research associate at the NBS Boulder, Colo., laboratories working with NBS scientists to develop test procedures for small computers and electronic office equipment.

In order to comply with a Federal Communications Commission regulation issued in 1982, the office equipment industry needs improved procedures and techniques that will minimize the amount of unwanted electromagnetic (EM) radiation given off by this equipment while preventing the equipment from being affected by environmental EM radiation.

PETROLEUM CRUDE OIL REFERENCE MATERIAL AVAILABLE

NBS researchers have developed a Standard Reference Material (SRM) for evaluating analytical methods used to measure trace organic constituents in petroleum oil samples. Known as SRM 1582, Petroleum Crude Oil, the new material will allow laboratories to check their measurements and determine how well they are performing the steps—sample preparation and handling, for example—required to analyze complex oil samples.

The material is certified to contain specified concentrations of six compounds on the Environmental Protection Agency's list of "priority pollutants"—benz[a]anthracene, benzo[a]pyrene, dibenzothiophene, fluoranthene, perylene, and phenanthrene. The SRM also is useful in evaluating analysis methods for similar compounds in alternate fuels such as coal-derived liquids. It complements an earlier-developed shale oil SRM and consists of five vials, each containing 2 milliliters of petroleum crude oil sample. SRM 1582 is available for $178 from the Office of Standard Reference Materials, B311 Chemistry Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2045.

CERAMIC POWDER CHARACTERIZATION LABORATORY ESTABLISHED

Advanced ceramics are being used in high-temperature engines and turbines, electrical capacitors, semiconductors, and other aerospace and electronic technologies. To help manufacturers, NBS has established a fine-powder laboratory that will enable scientists to conduct basic research on key "powder signatures" that will permit them to quantitatively correlate powder characteristics with the physical and chemical properties in finished ceramics.

The new NBS ceramic powder characterization laboratory contains several clean room stations for use in determining the physical properties of ceramic powders as small as .003 micrometer. It is equipped to permit researchers to make small-particle materials; determine particle size and measure distribution of powders in unfired materials or measure particle grains in sintered (fired) materials; classify or size fractionation of powders; and measure physical properties of powders, green-state (unfired), and finished ceramic products. Cooperative programs with university and industry scientists will be undertaken in the new facility. For more information on this facility, write or call Samuel J. Schneider, A257 Materials Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2845.

INDUSTRY TO WORK AT NBS ON POLYMER MATERIALS

Bethlehem Steel Corporation's Homer Research Laboratories is sponsoring a research associate at NBS to study the piezoelectric and pyroelectric properties in polyvinylidene fluoride polymers. Dr. John R. Kastelic, from Homer's Deformation Processes Division, will use NBS technology as a basis for developing a commercial transducer material. He will characterize films produced by Bethlehem for potential use in pressure sensors and thermal and acoustic detectors.

NBS offers a wide variety of research tools within a single laboratory, as well as a staff of scientific experts with more than 10 years experience in polymer piezoelectrics. Kastelic will work with NBS scientists to perform thermal pulse experiments to measure the distribution of electrical charges in the interior of polymers. He also will use the NBS dielectric spectrometer, various x-ray instruments for crystallographic studies, a differential scanning calorimeter, and other devices to measure molecular properties of polymers under stress at both static conditions (for several minutes or longer) and dynamic conditions (as little as 10 milliseconds).

The NBS Research Associate Program provides an opportunity for people from industry, professional societies, and other organizations to conduct cooperative research at NBS on projects of mutual interest, with their salaries paid by the sponsor.

INTERNATIONAL MEASUREMENTS FOR ORGANOTINS UNDER STUDY

At the request of the Office of Naval Research, NBS is conducting the first international laboratory comparison of organotin measurement methods. The results will be used to develop a reliable reference material and recommended measurement methods for use by those trying to detect organotin in the environment and to determine the element's effect on biological processes.

Over the past 25 years, worldwide production of tin has expanded to a point where toxic exposure from organotin compounds used as stabilizers in plastics and as biocides in antifouling agents exceeds the amount of tin that is released by the natural weathering of the Earth's crust. To carry out the comparison, NBS has developed a special organic compound solution of tributyltin that has been sent to more than 45 industrial, academic, and government laboratories worldwide. The research samples may be analyzed for either total tin or organotin species. The results are to be returned to NBS for statistical analyses and evaluation of the measurement method that was used by each laboratory.

PLATING PROCESS TO IMPROVE USE OF CHROMIUM DEVELOPED

At the request of the American Electroplater's Society, NBS has developed a process, and applied for a patent, to electrodeposit binary nickel-chromium and cobalt-chromium alloys on plain low-carbon steel or aluminum surfaces.

It is estimated that up to 30 percent of imported chromium can be saved if low-carbon steels are substituted for bulk stainless steels which contain a large percentage of chromium and nickel. Many of the desired performance properties of stainless steels are required only at the surface of the material. Alloy coatings of nickel with chromium show superior wear performance and corrosion resistance when compared with commonly used bulk 316 L stainless steel.

For information on the plating process, contact: Dr. David S. Lashmore, B162 Polymers Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2958. For information on licensing agreements, contact: Office of Government Inventions and Patents, NTIS, P.O. Box 1423, Springfield, VA 22151, 703/487-4732.

MATERIAL TO HELP EVALUATE PERFORMANCE OF KEY MEASURING DEVICES

NBS has issued a new Standard Reference Material (SRM) for evaluating the performance of coordinate measuring machines (CMM's). CMM's report the three-dimensional coordinates of the tip of a probe which is moved over the surface of the object that is being measured. Physical limitations introduce small errors in the reported position of the probe tip, and CMM users must be careful to purchase machines accurate enough to meet their requirements. To date, however, no single agreed-upon method for assessing the accuracy and precision of such machines exists. Recently, the American Society of Mechanical Engineers released a trial standard to provide such a method. The new NBS reference material, Socketed Ball Bar (SRM 208), is designed for use with this proposed standard. Ordering information is available from the Office of Standard Reference Materials, B311 Chemistry Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2045.

NEUTRON SCATTERING USED TO STUDY STRUCTURES IN EPOXIES

NBS scientists are looking at the microscopic structures in cured epoxy resins with a small angle neutron scattering (SANS) technique. SANS, a nondestructive tool that uses low-energy neutrons to characterize three-dimensional properties in materials, permits researchers for the first time to study the uniformity of crosslinking networks that grow out of polymer chains.

Crosslink density distribution is a major factor in determining the structural properties of cured polymers. This information will help scientists to predict product performance and assist manufacturers in controlling curing processes. This type of information is especially useful in the production of graphite fiber composites for high-performance aerospace components and sports equipment and fiberglasses for molded items, housewares, and automobile bodies. For information on the characterization analysis, contact: Drs. Donald L. Hunston, Wen-Li Wu, or Barry J. Bauer, A209 Polymers Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-3318.

CORROSION ENGINEERS' RESEARCH ASSOCIATE TO DEVELOP DATA

The National Association of Corrosion Engineers has selected David E. Clausen, a materials scientist experienced in the use of computers, as a research associate for the NBS Corrosion Data Center. Clausen will work with NBS researchers in providing industry with critically needed data for the design of industrial plants, structures, equipment, and other products that are susceptible to corrosion.

In the Corrosion Data Center, researchers will use computers to store and evaluate data collected from the literature, companies, and trade associations. Clausen will help develop computer graphics that will provide basic information for designers and help others in diagnosing corrosion failures.

Corrosion data can be divided into two classes of information: thermodynamic data that deals with the long-term stability of metals and kinetic data that shows the rate of the corrosion process.

GATT REPORT ON TECHNICAL BARRIERS TO TRADE PUBLISHED

Manufacturers, exporters, and others concerned with international trade will be interested in the annual report on GATT Standards Code Activities of the National Bureau of Standards (SP 678). NBS is the official U.S. GATT (General Agreement on Tariffs and Trade) inquiry point for standards-related notifications from the GATT Secretariat in Geneva, Switzerland.

The GATT report lists, by country and product, proposed foreign mandatory standards and certification systems that may create technical barriers to trade. Other activities reported include assistance to industry to solve standards-related trade problems, coordination of comments from industry on proposed foreign regulations, translations of texts, and the NBS GATT "hotline" that provides the latest information on foreign notifications.

For copies of the report or for information on the GATT inquiry point, contact: JoAnne R. Overman, Standards Code and Information, A629 Administration Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2092.

USING A SYSTEMATIC APPROACH TO SOLVE EMI PROBLEMS

The proliferation of sources of electromagnetic (EM) radiation in recent years has created some extremely hostile environments within which electronic equipment must operate, especially where there are dense concentrations of both high-powered EM radiating sources and sensitive receiving equipment. The result has been increasing numbers of complex electromagnetic interference (EMI) and electromagnetic susceptibility problems. NBS engineers have been successful in reducing EMI levels in several practical applications by utilizing a systematic approach they developed to attack this type of problem. A paper describing a particular situation and outlining the problem-solving approach used is now available by contacting Fred McGehan, Division 360.2, National Bureau of Standards, Boulder, CO 80303, 303/497-3246.

DEADLINE SET FOR FIRST ASSESSMENTS OF FILM TESTING LABS

The application deadline for on-site assessments of laboratories that test film for microforms—microfilm, microfiche, aperture cards—and other photographic film is December 1, 1984. The new laboratory accreditation program (LAP), which will serve a $5 billion market, was established by NBS as a part of its National Voluntary Accreditation Program at the request of the Association for Information and Image Management (AIIM).

The "film LAP" will provide regulated industries, utilities, financial groups, and governments with a list of testing laboratories that are able to ensure that photographic film used for record maintenance and for copying important historical documents is manufactured and processed to the standards and test methods included in this program. For additional information or an application package, contact: Manager, Laboratory Accreditation, A531 Administration Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-3431. ■

Standard Interfaces Key to Factory Automation

"About 1970 we decided that the two most important areas of NBS concern in the manufacturing industries—measurement science and standardization—were going to be revolutionized by the introduction of the computer," recalls Dr. John Simpson, director of the NBS Center for Manufacturing Engineering.

That revolution led NBS to a new way of thinking about the machine shop and how it functions. "We now believe," says Simpson, "that the factory of the future will look like the computer installation of today, except that the 'peripherals' will have muscles. Instead of printers and plotters you will have lathes, milling machines, and robots."

The factory may be in the future, but much of the technology that will make it work is here today at NBS, where engineers, machinists, and computer specialists from industry, government, and academia are at work on the Bureau's unique Automated Manufacturing Research Facility (AMRF).

The AMRF, which, as Simpson promised, looks like a cross between a computer installation and a machine shop, is a research testbed—the equivalent of an electronics technician's "breadboard." NBS is building the facility to study fundamental questions affecting factory automation, questions that affect the modernization and competitiveness of American industry. What is the best way to develop standardized "interfaces" between different types of equipment? What are the most useful "architectures" for manufacturing systems? How do you provide for accurate measurements—consistent with national standards—and quality control in an automated shop?

Cooperative research programs that draw on the expertise of both NBS scientists and researchers from private organizations and other government agencies are an important factor in the Bureau's program.

The Navy Manufacturing Technology Office is a major partner in the AMRF, because the Navy looks forward to significant cost savings when advanced automation research is applied to the manufacturing and warehousing of spare parts. Thirty-four researchers from industry have worked at the AMRF over the past 3 years, and a number of private firms and universities have contributed to the project by loaning guest workers and equipment. The Air Force Intelligent Task Automation Project and other government agencies have also sponsored specific parts of the AMRF effort.

When the facility is fully operational in 1986, it will include several types of automated machine tools, such as milling machines and lathes, automated materials-handling equipment (to move parts, tools, and raw materials from one "station" to another), and a variety of industrial robots to tend the equipment.

The entire facility runs under computer control using an advanced control system pioneered at NBS. The AMRF "factory" incorporates the most advanced automated manufacturing control techniques in the world.

In November 1983, NBS ran the first stage of the AMRF, a demonstration that included two computer-controlled machine tools, two industrial robots, a robot cart to move materials around, and a complex computer network that coordinated the entire facility under a high-level control system. No two components came from the same manufacturer. The system used 34 "standard" interfaces between different pieces of equipment.

Interface Standards

The AMRF researchers have a favorite metaphor for their view of the future—machine tools, robots, and computers should plug together with the ease of a component stereo system. And the user should not be required to have a degree in computer science.

Why? Economics. Specialized, flexible manufacturing systems already exist, and they are within reach of our large industrial firms. All that is required is sufficient resources—tens of millions of dollars—to buy a completely integrated automated factory or to hire the experts necessary to work out complex interfaces between otherwise incompatible equipment.

But close to 90 percent of the firms in the discrete parts industry—about 100,000—are small firms with fewer than 50 employees.

The only feasible way for such companies to adapt to a world of automated manufacturing is incrementally—buy one sophisticated machine tool this year, operate for a year or two until the profits make it possible to buy, say, a computer-aided process planning system, eventually buy a second machine tool, and so forth.

Such companies need the flexibility to buy from different manufacturers at different times with the assurance that the machines they buy can be made to work together in the same control system without expensive, custom-designed interfaces.

When the typical "production run" is comparatively small—say, less than 1,000 of any one part at a time—the manufacturer needs a system flexible enough to switch from the production of one part to another quickly and without expensive reprogramming. It is worth noting that even the most advanced flexible manufacturing systems of today are limited in their repertoires to a few families of generally similar parts.

How can all this be accomplished? According to the AMRF researchers, by the clever use of software (computer programs) and an intelligently designed control system.

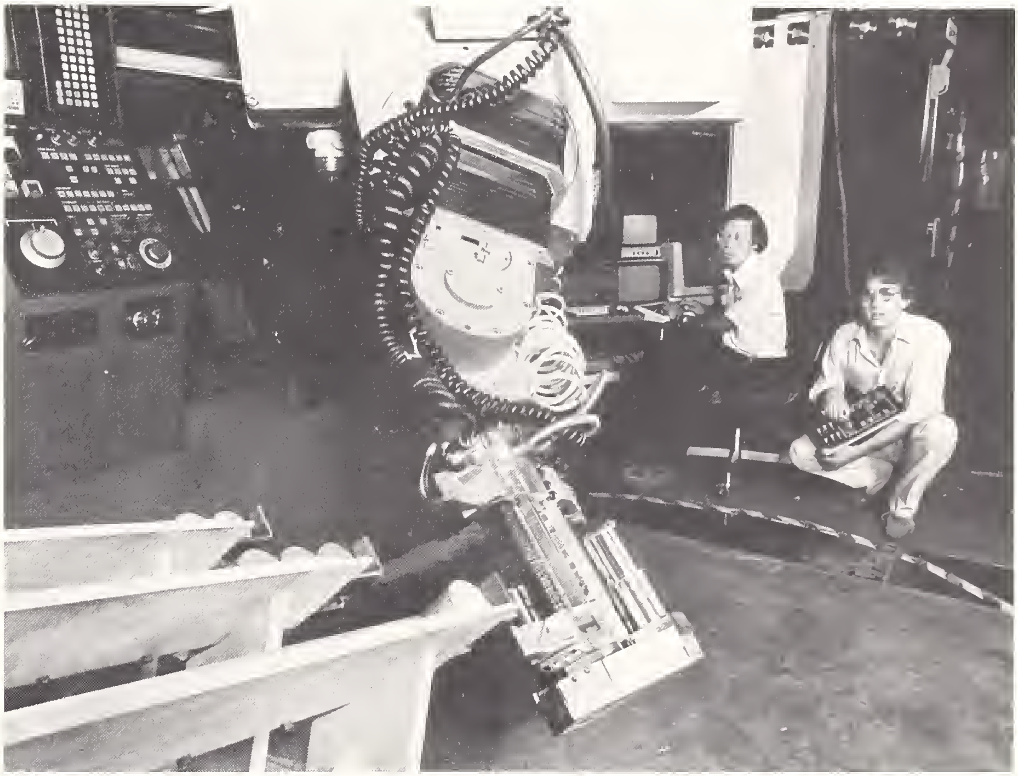
"If you write your control software in a proper, highly structured, highly disciplined fashion, you can have plug-to-plug compatibility for your machines and computers," says Simpson. "We believe we know how to set up such a control system, and last November we proved that such a system can work."

The Software Solution

"One effect of the arrival on the shop floor of the computer and the microprocessor is that they are teaching production engineers to think more formally and more rigorously," according to Simpson. Nowhere is this more evident than in the control structure devised by NBS engineers to manage the Automated Manufacturing Research Facility.

The modular, highly structured programs that run the AMRF have several features of interest to the builders and users of modern machine tools.

The various subprograms are not only modular, they also follow strict rules of format. Various parts of the system can be removed or replaced, as needs dictate, without major changes to the rest of the program. And since all the modules look somewhat alike—strict formats—they are easy for humans to understand and "debug."



NBS engineer Kang Lee (seated) and technician Michael Huff run tests on a robot at the AMRF Turning Workstation. This robot uses a precision gripper mechanism invented at NBS for the delicate task of loading part blanks into the collet of an automated lathe.

Control functions and data are kept strictly separate. The entire facility is—in the words of project engineers—"data-driven," that is, the motions that any machine in the facility goes through to produce a part are based on the description of that part in a database of the sort produced by computer-aided design (CAD) systems. This is in contrast to present-day manufacturing systems that require a separate program for each part or family of parts. Changing the part manufactured by the AMRF requires only a change to the part-description database, not a completely new program.

The sensor systems required to monitor the AMRF also use this database. For example, a unique feature of the robot vision system used in the AMRF is that it does not need to be "taught" to recognize a new part—it knows what the part should look like from its description in the database.

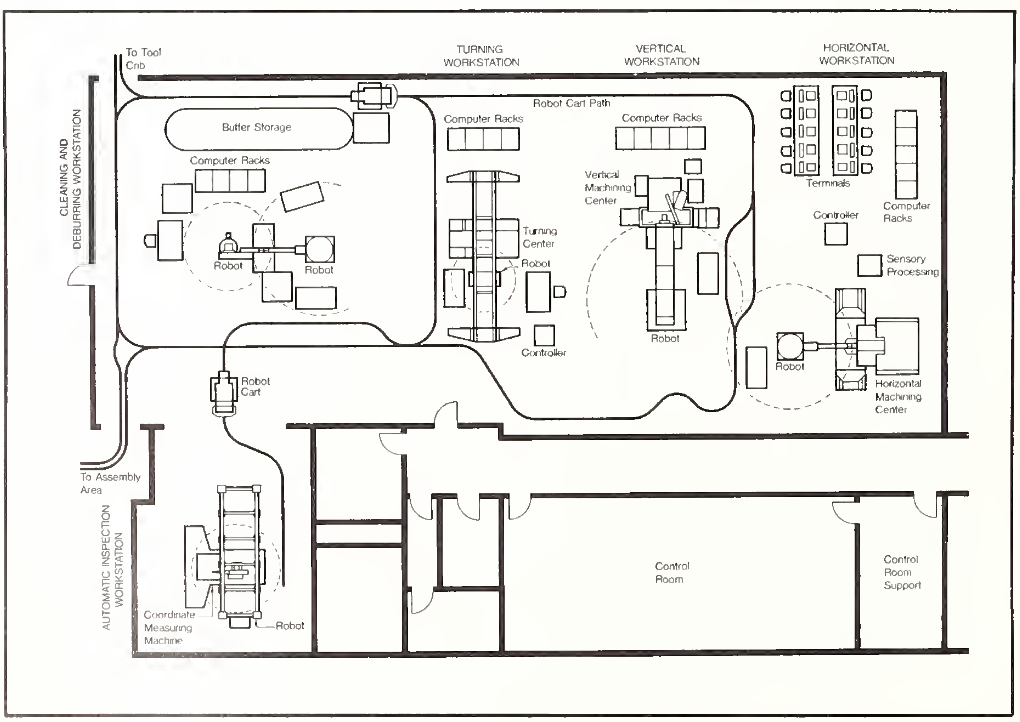
The interface between any two machines in the AMRF is a common area of memory, where the necessary information is stored in a standard format. "The idea," says Simpson, "is that you never let any machine call up another on the phone, because they might interrupt something important. You require them to leave messages for one another in memory 'mailboxes'."

The "mailbox" system has several advantages. For machine-tool manufacturers, it means that no outside parties need know anything about their proprietary control systems and programming languages. No machine in the system needs to know anything about any other machine except the address of its "mailbox."

It also means that the NBS control system does not tie the AMRF to any one programming language. "We feel that there is no one language for everything you might wish to do in a factory," notes Simpson, "and therefore an attempt to standardize a language probably will not work. One of the powers of our scheme is that it is comparatively easy to agree on the data to exchange and the format of that data, and you do not have to specify a language. Right now we are using Praxis, RATFOR, Lisp, PROLOG, C, and Forth."

The control system behaves like an "expert system." The control programs at each level of the AMRF are structured as a series of directives in the form of "IF (some condition occurs) THEN (do the following things)." The last item in the list is always "IF (anything else) THEN (ask for help)." (These are called "state tables" by computer specialists.) Whenever an unforeseen condition occurs, the system stops and asks for directions, at which point an engineer must figure out the problem and the appropriate solution, which is then added to the "state table." As a result, the system gradually absorbs manufacturing knowledge from its users, and the older the system is, the "smarter" it gets. Artificial intelligence researchers call this a sort of "expert system."

The Bureau's researchers are optimistic that they can convince industry of the merits of their system. "We believe that you pay a very small price to have a properly configured control system," says Simpson, "and we do not believe that adding the ability to interface to this system will increase the cost of the product that much. We will see."



This floor diagram shows the arrangement of workstations in the AMRF. Most of the machinery, with the exception of the automated storage equipment in the upper left corner, is now in place.

Quality Control

There is another side to the NBS automation program, the result of the Bureau's traditional goal to supply industry with an accurate system of measurements for quality control. For much of the manufacturing industry, this means supplying gage blocks and screw-thread gages calibrated against national standards.

But this too is changing, say NBS researchers, with the arrival of the microprocessor. Historically, manufacturing and measuring have always been two separate processes. For instance, a machinist will shape a part on a lathe and stop periodically to check dimensions with calipers and gages, or an automated machine will be set to produce a particular part, and the resulting products will be measured to assure that they are "in tolerance."

If the two processes could be done at the same time, so that machining a part would be the same as measuring it, the system would be many times more efficient. It would take less time and there would be fewer parts scrapped because they are out of tolerance.

The thing to do, according to NBS researchers, is to take advantage of the fact that with modern, computer-controlled machine tools, the position of the cutting edge of the tool is known and controlled at all times, at least in theory, by the computer. So why not make the tool a measurement probe?

"The key," says Simpson, "is to realize that if there are no people involved in the actual manufacturing process, then the system is completely deterministic. In other words, if the system ever once produces a good part, then something has to change before it can produce a bad part. With the appropriate sensors and feedback mechanisms, you can detect that change and take corrective measures before a bad part is actually produced."

Looked at another way, continues Simpson, the NBS approach to quality control is to push the theories of Dr. Arthur Deming, a folk-hero in quality-control circles, one step further.

"Deming, you may recall, said that you can get useful information on the performance of your manufacturing processes by making appropriate measurements on the products and applying statistical analyses. You then can use that information to improve your quality control," explains Simpson. "What we are saying is that instead of using the product to monitor the process, it is now possible to monitor the process itself, and so control the quality of the product."

In practice this means that each machine must first be analyzed to determine how it errs. Most such machines can position the tip of a drill, for example, anywhere within a three-dimensional "work space," but there will be a difference between the actual location of the drill tip and its "nominal" position according to the machine's control system. This is a "static" error, caused by minor inaccuracies in the machine's parts, and it is very predictable. AMRF engineers use laser interferometry and similar techniques to "map" these static errors, and then program compensating "offsets" into the control system.

Machine tools are also subject to "dynamic errors," errors that change with operating conditions. As a machine heats up or cools down, for example, its parts expand or contract, and this affects its ability to position a tool accurately. The treatment is to measure the degree of error introduced as the machine's temperature changes and to mount temperature sensors on the critical parts. The control system then can monitor the temperature itself and make appropriate corrections.

For machine-tool manufacturers, it means that no outside parties need know anything about their proprietary control systems and programming languages.

NBS researchers have applied these ideas to a standard vertical machining center and improved its performance in terms of accuracy and control by five to ten times.

Other sensors can check for more unpredictable problems. Faced with a common manufacturing problem—drill breakage—NBS engineers built a small microprocessor-controlled device which "listens" to the sound made by a bit as it drills holes. As it turns out, the sound made by a drill in the fraction of a second before the bit breaks is very distinctive and, through the monitor (dubbed "Drill-Up" by its inventors), the control system can detect this sound and pull the drill up before it breaks.

Will American companies adopt the ideas and techniques of the AMRF? That is already happening. One company has adapted NBS-developed error-correction techniques to the control system of its machining centers, and another is developing a commercial version of "Drill-Up." The list of large and influential companies that work with NBS on the AMRF project guarantees that the results of this research at least will receive serious consideration in private industry.

Where is all this technology leading? One thing is sure, according to Simpson, it will change the jobs of plant engineers and machinists. "They will need to think more in terms of systems, the way computer scientists do. Our own staff runs about 2-to-1, computer scientists to mechanical engineers," says Simpson.

As for larger social effects, he says, "it will be another several years before we find out if this new technology is a force for industrial aggregation or disaggregation. It could simply lead to more and more vertical integration in the industry, with fewer and fewer small companies.

"But it might lead to small, disaggregated firms. The Norwegian government, for example, is pushing this route as a way to avoid the social problems of large cities. You can do it. With world databases, satellite communications, small flexible manufacturing systems, it is technologically possible."

by Michael Baum
NBS Public Affairs Specialist

Standard Data Formats: Transferring Part Designs Between Systems

One of the most important concepts used in the NBS Automated Manufacturing Research Facility is the standardization of data formats and the use of common-memory "mailboxes" as interfaces between separate modules of the integrated system.

The AMRF is not the first application of that idea, however. It has already achieved commercial success among computer-aided design (CAD) system users as the Initial Graphics Exchange Specification (IGES).

Five years ago CAD system users were in about the same situation as automated machine tool users today. There was a broad selection of commercial CAD systems available, each with its own software and method of representing data, no two of which were alike. If you needed to transfer a part design from one system to another, you would have to have the first system produce the appropriate drawings of the part, carry them over to the second system, and re-enter all of the data. The users were not happy about this.

IGES began in a meeting at the National Academy of Sciences on October 11, 1979. There, representatives of the three branches of the military, the National Aeronautics and Space Administration, NBS, and suppliers and users of CAD systems discussed existing efforts to write interface standards for CAD systems and created the IGES Technical Committee, under the sponsorship of the Air Force Integrated Computer-Aided Manufacturing Program.

NBS agreed to direct and coordinate the effort, and a joint industry-government group, with technical assistance from Boeing and General Electric, produced the first draft of the graphics exchange specification in 3 months. IGES Version 1 was adopted by the American National Standards Institute (ANSI) as a major portion of its standard Y14.26M ("Digital Representation for Communication of Product Definition Data") in September 1981, and has been advanced for recognition as an international standard.

IGES provides a format for the drawings and the three-dimensional part models typical of CAD systems. Designers and engineers can transfer data between otherwise incompatible CAD systems by using the IGES format as an intermediate step.

In practice, each CAD system manufacturer that wants to sell a machine compatible with IGES simply writes an extra program that translates data from the internal system used by the machine to the IGES format (and back again). There is no need to reveal any of the (usually secret) details of the internal system.

A formal committee structure, still coordinated by NBS, has been set up to continue work on IGES. Last year IGES Version 2 was released to extend the range of the specification to the types of data found in electronic "printed" circuit board design and finite element models.

In July, six companies and federal agencies agreed to cooperate on a 1-year test of an extension that would expand IGES to encompass modeling systems that use solid geometry to represent objects. NBS, Bendix Corporation (Kansas City), the Ford Motor Company, the General Electric Automation Systems Laboratory, the National Aeronautics and Space Administration, and Structural Dynamics Research Corporation will build translators to test the effectiveness of the experimental solids proposal. Solid models are important in design and engineering when it is necessary to compute the weight or volume of a part, model the structural or thermal performance of a part, or find out whether a particular design calls for two parts to occupy the same space.

IGES has been publicly demonstrated several times, most recently in November 1983, at AUTOFACT 5, when 12 major vendors of computer-aided design/computer-aided manufacturing systems joined together to demonstrate that they could transfer a typical mechanical part data file accurately from one system to another. Industry figures indicate that IGES-translation capability is now offered by over 80 percent of the CAD industry.

For additional information on IGES, write or call Bradford Smith, IGES Coordinator, A353 Metrology Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-3691.

How To Secure Your Computer Systems

Until a few years ago, "hacker" meant someone who drove a cab or coughed a lot. Recently, it has come to mean someone who trespasses in another's computer files.

But, while hackers can cause problems, most experts agree that the computer security problem is much larger. Computer information, they say, must be guarded from loss by operator error, natural disasters, and sophisticated high-technology attacks on classified systems.

Security experts also agree that there are many straightforward and relatively inexpensive countermeasures. Dr. Stuart Katzke, an NBS computer security expert, asserts that "between 80 and 90 percent of the problems have been addressed by the computer security community and could easily be avoided by using available management and technical solutions." Katzke says these include ways to protect against cross-country break-ins made by dialing into an organization's computer system via a telephone link-up, by getting unauthorized access to computer rooms because of lax physical security, or by other relatively simple routes.

NBS is not a regulatory agency, but through its Institute for Computer Sciences and Technology (ICST) the Bureau has a special responsibility to help organizations manage and use computers effectively. For more than 10 years, NBS specialists have been developing cost-effective methods to protect data. These methods include sound management practices as well as automated techniques that are integrated into computers and terminals. In developing these practices and techniques, NBS works with users and industry to find out what their needs are and to stimulate development of off-the-shelf commercial products.

Computer researchers Dennis Branstad (standing) and Stuart Katzke investigate techniques for protecting data in computer systems.

According to Katzke, manager of ICST's computer security management and evaluation group, the first step toward protecting data is to form a comprehensive computer security program. Although this may seem obvious, Katzke says, it is a step that often is overlooked. Such a program should help make computer security an integral part of management and keep everyone in the organization more aware of problems and solutions.

One safeguard that users can apply is a password system to identify authorized computer users. "Passwords are among the least expensive ways to protect data," says Dr. Dennis Branstad, who heads ICST's computer integrity and security technology

This standard specifies a cryptographic algorithm for protecting unclassified but sensitive data that is transmitted between terminals and computers or between computers.

group. "If properly used, they provide a reasonable level of control over who has access to a computer system."

NBS soon will issue a standard with basic guidelines for designing and putting into place a password system. For example, a password should not be used longer than 1 year and should be changed as often as is practical.

Also, passwords should be selected at random and should not be tied to a user's identity. In other words, says Branstad, it is not a good idea to use the name of your spouse or child or even the family pet. And you should not choose a word related to your profession. So, a poor choice for a banker's password would be "money" or "check."

But passwords may not be enough to protect some systems. Branstad and his staff have been investigating other techniques and devices designed to keep unauthorized people out of computer systems. Some of the devices they have looked at include automated signature verifiers and machines designed to match fingerprints or hand contours against those already on file.

"In our laboratory experiments, we have found that while many high-technology identification systems work quite well, they are often too expensive for applications that involve identifying a computer user at a remote terminal," Branstad says.

Probably the best way to ensure that data cannot be read, according to Branstad, is to encrypt it—or scramble the information—so only those with a "key" can unscramble it. In 1977, NBS published the Data Encryption Standard. This standard specifies a cryptographic algorithm for protecting unclassified but sensitive data that is transmitted between terminals and computers or between computers.

NBS has been working with the financial community to develop standards needed to protect financial networks. Its encryption standard has been adopted by the American National Standards Institute and the American Bankers Association for protecting transfers of funds and securities over communications lines, a process known as electronic funds transfer (EFT). And, the Department of the Treasury has drafted a policy calling for all such federal EFT systems to use equipment which relies on the NBS standard.

Several manufacturers have begun producing devices based on the NBS standard, and such systems are available for as little as $295.

In 1983, NBS computer scientists Miles Smid and Branstad received a U.S. patent for developing a way to further protect data. Used in conjunction with the encryption standard, the Key Notarization System notarizes or "seals" the key used to scramble and unscramble data with the names of the transmitter and intended receiver.

With NBS assistance, the Department of Energy has used the key system at several of its national laboratories. The financial community is considering making it part of its voluntary industry standard on cryptographic key management.

No matter how secure a system seems to be there is still the chance that an accident may damage or destroy valuable data. The NBS experts recommend that organizations be prepared to recover from major disasters such as floods as well as disruptions from hardware and software failures and operator errors. While the latter may seem minor, they are more of a problem because they can occur more frequently.

With the proliferation of small desktop computers and networks,

NBS experts recommend that organizations be prepared to recover from major disasters. . .as well as disruptions from hardware and software failures and operator errors.

both Katzke and Branstad agree the potential for problems is increasing. But, Katzke says computer owners are starting to realize that their systems are vulnerable and they are beginning to "lock their electronic doors."

He adds, "It is going to take a while for everyone to get the word." In the meantime, the computer security experts at NBS will continue to investigate new locks and develop ways to protect the keys.

by Jan Kosko
NBS Public Affairs Specialist

For More on Computer Security . . .

In the process of developing methods for protecting data in computer systems, NBS researchers have produced a number of publications. The following list is a sample of the computer security publications that are available. For further information on the NBS computer security program or to get a complete list of NBS computer security publications, write or call the Institute for Computer Sciences and Technology, B253 Technology Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-3414.

Send orders for the publications below to National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

Data Encryption Standard, *FIPS-PUB-46 (January 1977), $7 prepaid*. Specifies an algorithm to be implemented in electronic hardware devices and used for the cryptographic protection of sensitive, but unclassified, computer data. The algorithm uniquely defines the mathematical steps required to transform computer data into a cryptographic cipher and the steps required to transform the cipher back to its original form.

Guidelines for Security of Computer Applications, *FIPS-PUB-73 (June 1980), $10 prepaid.* Describes the different security objectives for a computer application, explains the control measures that can be used, and identifies the decisions that should be made at each stage in the life cycle of computer systems which require protection.

Guidelines for Implementing and Using the NBS Data Encryption Standard, *FIPS-PUB-74 (April 1981), $8.50 prepaid.* Provides guidance for the use of cryptographic techniques when such techniques are required to protect sensitive or valuable computer data. For use in conjunction with FIPS-PUB-46 and FIPS-PUB-81.

DES Modes of Operation, *FIPS-PUB-81 (December 1980), $8.50 prepaid.* Defines four modes of operation for the Data Encryption Standard which may be used in a wide variety of applications. The modes specify how data will be encrypted and decrypted. Included in this standard are the electronic codebook (ECB) mode, the cipher block chaining (CBC) mode, the cipher feedback (CFB) mode, and the output feedback (OFB) mode.

Guideline on User Authentication Techniques for Computer Network Access Control, *FIPS-PUB-83 (September 1980), $8.50 prepaid.* Provides guidance in the selection and implementation of techniques for authenticating the users of remote terminals in order to safeguard against unauthorized access to computers and computer networks. Describes use of passwords, identification tokens, verification by means of personal attributes, identification of remote devices, role of encryption in network access control, and computerized authorization techniques.

Guidelines for ADP Contingency Planning, *FIPS-PUB-87 (March 1981), $8.50 prepaid.* Describes what should be considered when developing a contingency plan for an ADP facility. Provides a suggested structure and format which may be used to design a plan to fit each specific operation.

Guideline for Computer Security Certification and Accreditation, *FIPS-PUB-102 (September 1983), $11.50 prepaid.* Describes how to establish and how to carry out a certification and accreditation program for computer security. Certification consists of a technical evaluation of a sensitive system to see how well it meets its security requirements. Accreditation is the official management authorization for the operation of the system and is based on the certification process.

Maintenance Testing for the Data Encryption Standard, *Jason Gait, NBS SP 500-61 (August 1980). Order from NTIS as PB 80221211, $8.50 prepaid.* Describes four tests that can be used by manufacturers and users to check the operation of data encryption devices. These tests are simple, efficient, and independent of the implementation of the Data Encryption Standard (FIPS-PUB-46).

Executive Guide to ADP Contingency Planning, *James K. Shaw and Stuart W. Katzke, NBS SP 500-85 (July 1981). Order from NTIS as PB 82165226, $7 prepaid.* Provides, in the form of questions and answers, the background and basic essential information required to understand the developmental process for automatic data processing (ADP) contingency plans. The primary intended audience is executives and managers who depend on ADP resources and services, yet may not be directly responsible for the daily management or supervision of data processing activities or facilities.

Cold Circuits Next Step in Electronics Revolution?

The electronics revolution has been spurred on by rapid advances in the development of large-scale integrated circuits, the driving force behind today's electronic products. But another kind of circuit technology being investigated at NBS and other laboratories holds the promise of making today's integrated chips look laggard by comparison. Extremely cold electronic circuits, based on superconductors instead of semiconductors, are at the heart of new devices already being put to use by NBS. The Bureau is using such "cryoelectronic" circuits to analyze and count electrical signals more quickly and to detect magnetic fields and electrical currents more sensitively than any other known instruments. Superconductors are metals and alloys that conduct electricity with no resistance whatever when cooled to temperatures near absolute zero (−460 °F). Besides having zero resistance, they exhibit several other related phenomena:

- An electrical current established in a superconducting loop will flow forever without additional power.
- Only an extremely strong magnetic field will penetrate the surface of a superconductor; most fields are simply repelled by the surface.
- If a superconductor is interrupted by a very thin insulating barrier, a Josephson junction is formed. Such junctions can be connected into circuits that detect magnetic fields more sensitively than any other known devices and can be made to produce precise voltage increments proportional to the frequency of an exciting current.
- Superconducting circuits have been produced that perform certain functions, such as logic, counting, sampling, and analog-to-digital conversion, faster than any other technology.

NBS is one of several research organizations blazing new trails into this relatively unexplored field. The Bureau's goal is to improve our ability to measure faster and more sensitively a wide range of phenomena important to U.S. industry, science, and defense.

Dr. Richard Harris, leader of the cryoelectronic metrology group at the Bureau's Boulder, Colo., laboratories, explains that the NBS program concentrates on the theory and experimental construction of superconducting circuits, rather than on development of new cryoelectronic materials.

"We are especially interested in devices useful for measurements, rather than for digital computation," he says.

One of the intriguing uses of cryoelectronics ("cryo" derives from the Greek, meaning "icy-cold") is the SQUID, or Superconducting Quantum Interference Device. A SQUID is essentially a superconducting loop interrupted by one or two Josephson junctions. SQUID's are exquisitely sensitive to changes in magnetic fields—for example, those associated with currents in the brain or heart. Information gained about brain or heart functions through SQUID's complements that of electroencephalograms and electrocardiograms and gives doctors a diagnostic tool that localizes the source of a signal more accurately than conventional techniques.

Sandro Barbanera, an NBS guest worker from the Italian National Research Council, points out that the SQUID magnetic measuring device uses a non-invasive technique that avoids the risks of catheterization and the errors inherent to skin-contact electrodes.

Barbanera works with Dr. James Zimmerman, an NBS researcher who was one of the inventors of SQUID's in the middle 1960's and who has been developing SQUID's for biomedical and other purposes for more than 15 years. Zimmerman comments: "While biomedical applications, particularly non-invasive brain research, are the most widespread and exciting uses of SQUID's today, there are numerous other applications. They include detecting unusual magnetic patterns in the ocean (to discover submarines, mines, or sunken vessels) and on land (to prospect for ore bodies or other subsurface features). In space, SQUID's are

To provide a more precise voltage reference for maintaining the U.S. legal volt, NBS is exploring the use of superconducting microelectronic circuits. Here, electronics engineer Richard Kautz lowers a prototype into a liquid helium dewar for testing.

used to measure weak interplanetary magnetic fields as well as geomagnetic fields close to Earth." Future applications may include very-low-frequency communications receivers (a leading prospect for shore-to-submarine communications). Another application of SQUID's is in several astrophysical experiments to try to detect gravity waves from outer space.

NBS' efforts in superconducting microcircuit technology extend beyond SQUID's to more complex kinds of circuits. Harris explains, "The objective is to establish cryoelectronic microcircuits as practical tools for meeting the demands on NBS for measurement support of U.S. industry and defense. Our program has three main facets: to demonstrate practical instruments of superior performance; to explore the fundamental limits of speed, accuracy, and precision in electromagnetic instrumentation; and to solve peripheral problems of practical instrumentation, such as developing a compact, self-contained refrigeration system to achieve the extremely low temperatures needed for superconducting instruments." Zimmerman and others have been working in this third area for several years.

"Using NBS-developed superconducting microcircuits, in only 6 years we have set 'world speed records' in high-speed sampling, counting, and analog-to-digital conversion, and other records in the sensitivity of magnetic field detection and millimeter wave detection," says Harris.

Samplers and converters are used to analyze electrical signals. For many of today's applications, they must operate extremely fast to detect and record the details of fast-changing signals. One potential use for a superconducting analog-to-digital converter is in military radar applications. For instance, it would be advantageous not to let an enemy know that its planes were being tracked by radar. To do this, the emitted radar signal would need to be "disguised" in a sea of simulated electromagnetic noise. A converter would be needed to process the returning echo so that a computer could subtract the noise and recognize the target. The converter is needed because a computer cannot process raw radar signals—first the signals must be converted into digital form.

Samplers are used to analyze repetitive signals, such as those used in computers or other electronic instruments, with extra-high resolution. They work by picking out a very narrow segment of the signal, measuring its value, and then on the next repetition, picking out an adjacent narrow segment, and so on. After thousands of segments have been examined, an accurate picture of the whole signal is built up in a computer's memory, from where it can be recovered and analyzed.

Dr. Clark Hamilton, who leads the subgroup working on samplers and converters, points out, "The speed of the superconducting circuit is its advantage: we have built converters that operate at 4 billion samples per second, and our samplers have achieved a resolution of better than 9 trillionths of a second. Both are roughly three times faster than semiconductor devices built to date, and we hope to achieve at least another factor of three in samplers and perhaps 10 in converters before we are through."

Ultra-high-speed counters also have been designed in the NBS labs, operating at up to 100 billion counts per second. These devices have possibilities in several applications, including accurate voltage measurement and signal averaging and integration.

Since one of NBS' missions is to provide measurement standards for science and industry, it is appropriate that the NBS labs are also using superconducting circuits to improve the nation's voltage standard. A standard (chemical) cell generates about 1 volt, but its value drifts with time, temperature variations, and other environmental influences. Using Josephson junctions, NBS can generate precise voltage increments that depend only on the frequency of an exciting current. That is noteworthy because frequency can be controlled and measured more accurately than anything else. So NBS uses the junctions to monitor the cells, and thus greatly improves their usefulness as standards.

Research is underway at NBS to try to build a circuit that could make the monitoring process easier and maybe replace the cells entirely. In January 1984, Dr. Jurgen Niemeyer, a guest worker from West Germany working with Dr. Richard Kautz of NBS, demonstrated an array of 1,474 Josephson junctions that produced a constant voltage of 1.2 volts when exposed to 90-GHz microwaves. Kautz says, "This demonstrates the feasibility of a much more accurate, convenient, and less expensive way to calibrate the standard cells. It may offer a replacement of standard cells for some applications, as well."

Cryoelectronic circuits are not likely to find their way into the average home as components of computers or televisions because of their need for refrigeration to near absolute zero and because those applications do not need the added speed and sensitivity. But for areas of communications and measurement that require those advantages, superconducting circuits offer a valuable alternative.

by Collier Smith
NBS Public Affairs Specialist

New Particles for Measuring Pigments, Flour, Blood Cells

Predictions abound about the super-pure pharmaceuticals and flaw-free alloys that will someday be made aboard factories in space. But the very first commercial product to be manufactured in space has already been produced aboard the space shuttle, and it may seem humble in comparison. As part of a larger program to explore the basic science affecting space-based manufacturing, researchers from the National Aeronautics and Space Administration (NASA) and Lehigh University have developed a process for making plastic beads in space.

Of course, these are not ordinary plastic beads. They are tiny polystyrene spheres, only 10 micrometers (about 1/2500 of an inch) in diameter, and they are more perfectly spherical than anything that can be made of comparable size on Earth.

NBS will have the honor of measuring and selling them. The spheres produced in space are the star attraction of a new line of small-particle Standard Reference Materials (SRM's) that will be used to calibrate instruments that measure the size of everything from human blood cells to paint pigments to gunpowder to flour.

They are tiny polystyrene spheres. . .and they are more perfectly spherical than anything that can be made of comparable size on Earth.

Manufacturers of such products, says Stanley Rasberry, chief of the Bureau's Office of Standard Reference Materials, are "all very interested in the size of the particles in their products and in trying to keep them within specifications." A photocopier toner with particles too large or too small may produce unreadable copies; pigments in cosmetics or paints may not blend as well as they should. Even ordinary flour must be ground to the right particle size if it is to produce bread with the right consistency.

The particle SRM program was begun, according to Rasberry, at the urging of ASTM, a voluntary industry standards group, following requests by manufacturers for better standards. "We had a real measurement gap in the range of 0.1 micrometer to 100 micrometers," says the SRM chief. In addition, notes NBS physicist Dr. Thomas Lettieri who heads the particle SRM certification process, "each company [manufacturing particle-measuring instruments] had its own standards and none of them agreed."

Particle SRM's, explains Rasberry, make it possible for manufacturers to evaluate their products with confidence. Each of the more than 900 different SRM's sold by the Bureau is carefully analyzed, and then one or more of its chemical or physical properties are certified by Bureau scientists. In the case of the small-particle standards, polystyrene spheres in several sizes, 0.1, 0.3, 1, 3, 10, 30, and possibly 100 micrometers, will be certified to have a certain diameter with a small measurement uncertainty. The certified spheres can then be used to calibrate or reset particle-measuring instruments to give correct readings.

It is more difficult, however, to make the perfectly spherical polystyrene particles needed for measurement standards 10 micrometers and larger than the smaller sizes, such as 0.3 and 1 micrometer, which have been made successfully on Earth.

The NASA project to make the spheres in space, which is headed by Dr. John W. Vanderhoff of Lehigh University, will allow the Bureau to extend the range of the particle SRM series to larger sizes than would be possible otherwise. Dale Kornfeld, a NASA chemist at the Marshall Space Flight Center in Huntsville, Ala., and coinvestigator for the space shuttle particle project, explains why.

The process of producing the spheres, says Kornfeld, is analogous to swelling millions of tiny sponges with water. Microscopic "seed" spheres made of polystyrene and suspended in water are mixed with a carefully measured amount of styrene monomer, individual styrene molecules. The monomer, which has a consistency similar to a light oil, penetrates the seed spheres and swells them from the inside out. When the process is conducted on Earth, the new, larger spheres rise to the surface because the oily monomer is lighter than water. Once at the surface, they tend to pack and clump together, distorting their shape.

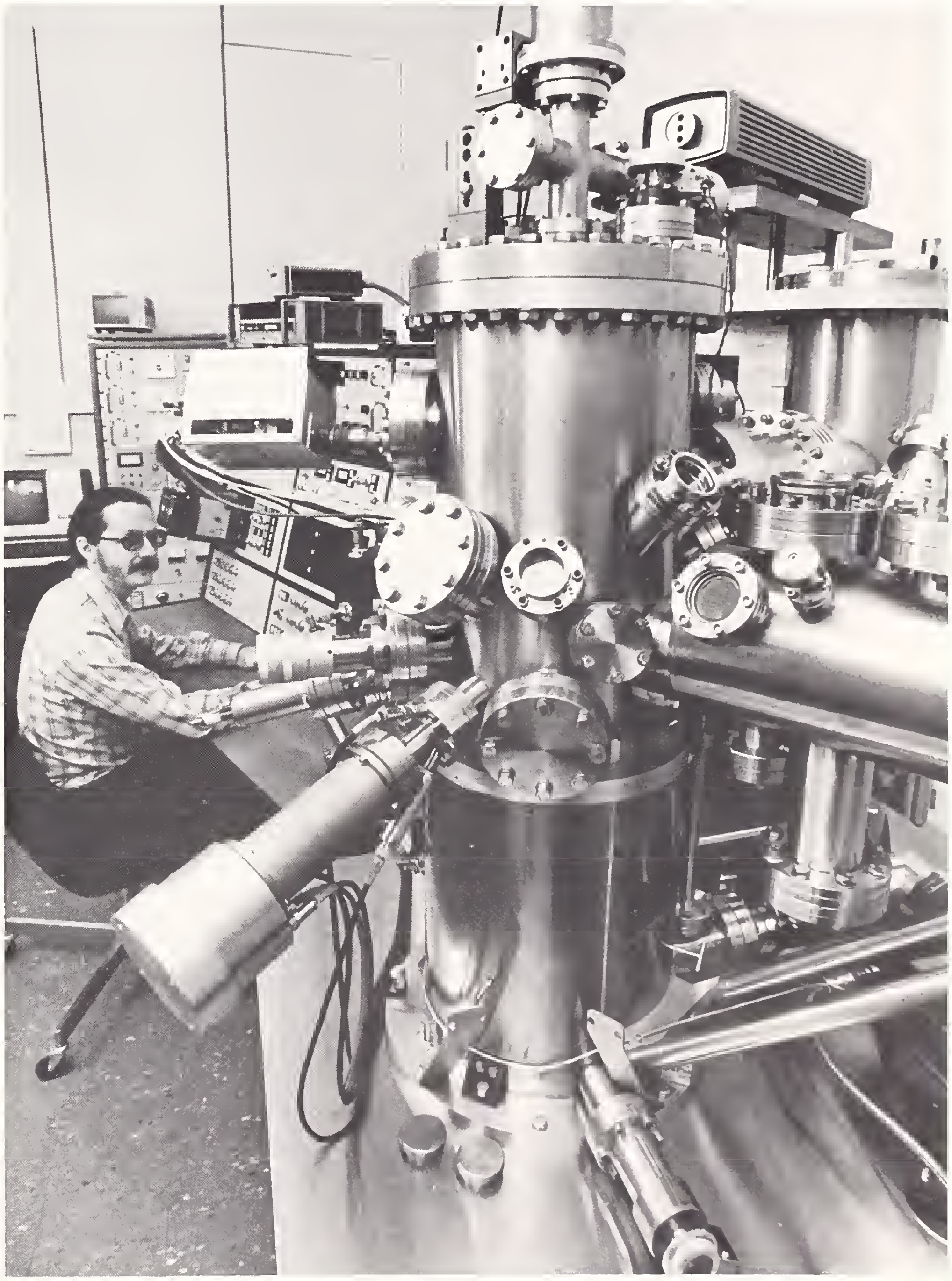
After the spheres are swollen, they are injected into a chemical reactor and "baked" to retain their new, larger size. Chemicals in the reactor cause the monomer molecules in the spheres to link together, or polymerize, turning the liquid droplets into solid beads. As the spheres solidify, they become heavier and sink to the bottom of the reactor. This once again causes clumping and distortion. Stirring can alleviate some of the problem, Kornfeld says, but when the spheres reach sizes as large as 10 micrometers, the liquid must be stirred so vigorously that the stirring itself causes clumping. As a result, a suspension that should look like skim milk ends up looking like cottage cheese instead.

The microgravity environment of the space shuttle in low Earth orbit eliminates these problems. The low gravity prevents the spheres from rising and falling and so they remain uniformly dispersed in the liquid throughout the swelling and polymerization process. Consequently, the particles can be made in batches that are much more uniform than similar-sized spheres made on Earth.

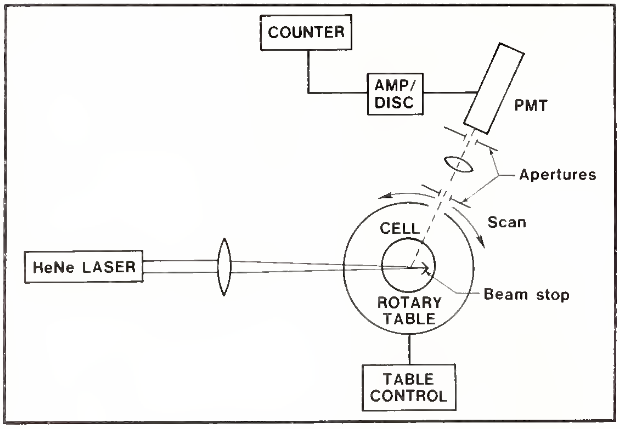
Uniformity is critical in the production of SRM's. The more uniform each SRM sample is, the more confident users of SRM's can be that their instruments will be calibrated correctly.

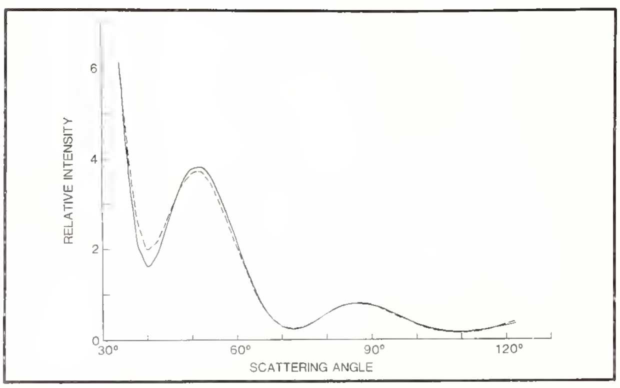
For example, SRM 1690, one of the small-particle reference materials, consists of a small vial containing millions of polystyrene spheres, each approximately 1 micrometer in diameter, in a water solution. Based on measurements performed by Bureau scientists, the SRM is certified to contain spheres with an average diameter of 0.895 micrometer and a standard deviation of about 0.008 micrometer. In other words, each sample drop of the SRM contains spheres that vary in size by only about 1 percent.

Accuracy is important because measurement error is introduced in each step of a manufacturing process. A company that sells particle standards in bulk to manufacturers may buy an SRM and use it to calibrate particle-measuring instruments used in their own quality control. Or the instrument manufacturers may buy the SRM to ensure the accuracy of their particle counters. For example, even when the particle standards or measurement instruments are used in a bread factory to regulate the grinding of flour,



Physicist Gary Hembree uses a scanning electron microscope to make electron profiles of the spheres which can be measured with a resolution of about 15 nanometers.





Top: Schematic diagram of apparatus used in laser light scattering technique. Bottom: Light scattering pattern for 1-micrometer-diameter polystyrene spheres. The dashed line represents the experimental data; the solid line shows the theoretical calculations.

additional error can be introduced. "We make the best measurements we can," says Lettieri, "so that the measurement uncertainty will still be acceptable by the time it gets down to the guy grabbing the flour out of the vat."

Bureau scientists achieve this high degree of confidence in their measurements by using at least two different measurement techniques to evaluate the same batch of SRM material. For example, the diameters of the small-particle SRM's will be certified using at least two of the following techniques: light scattering, optical microscopy, or scanning electron microscopy.

The first of these techniques, light scattering, utilizes a laser and a photoelectric detector. Just as the size of a large object can be gauged by the size of the shadow it casts on a wall, the size of small particles can be determined by noting the behavior of the laser beam passing through a solution in which the particles are suspended in water. The detector is mounted on a movable platform so that the intensity of light scattered by the particles can be measured from many different angles. The pattern of light scattering is then compared with the patterns predicted by equations for various sizes of spheres. The particle size is determined from the theoretical curve that most closely matches the actual pattern of light scattering.

Light scattering can also be used to measure individual spheres rather than many spheres in solution. One technique uses electrostatic levitation and involves trapping individual particles with an electric field. A sample of the spheres in solution is first sprayed into a closed chamber. Using a microscope to view the particles, researchers adjust the voltage in the chamber until a single sphere is caught within the electric field and the laser beam. The light scattering pattern from the trapped sphere is scanned in much the same way as in the technique described above.

A similar light scattering method uses optical levitation of the particles. In this relatively new technique, a single particle is trapped in the laser beam using its radiation pressure; the intense light from the laser beam actually supports the particle in mid-air. Once the sphere is stabilized in place, the frequency of the laser radiation is changed until the particle resonates or vibrates. A large particle will resonate at a lower laser frequency than a smaller one, the same way that a large bell vibrates at a lower frequency than a small bell. The frequencies at which the spheres

Particle SRM's, explains Rasberry, make it possible for manufacturers to evaluate their products with confidence.

resonate make it possible to calculate their sizes very precisely. Lettieri calls this method "the ultimate" in particle sizing and says, "We would like to see how far we can push this technique."

Lettieri and his coworkers recently built an optical levitation light scattering instrument and plan to use it to measure the 10- and 30-micrometer spheres manufactured on the space shuttle. Lettieri wants to be able to make measurements 100 times more precise than is possible with other light scattering techniques. The resolution of the new instrument, he says, should be about 1 nanometer or about the width of a few atoms.

The other two methods used by Bureau scientists to measure the spheres involve more direct approaches, but are no less sophisticated in their execution. NBS physicist Arie Hartman uses an optical microscope to measure the spheres directly against another SRM, a finely calibrated linewidth standard. Hartman smears a drop of the spheres in solution on a glass microscope slide and allows the water to evaporate. He then scans the slide for a region where the spheres are closely packed into an easily measured array. Comparing the total width of about 20 spheres against the linewidth standard, and dividing by the number of spheres in the array, he arrives at an average diameter. This process is repeated several times with different arrays.

To ensure that each set of spheres is measured in exactly the same way, Hartman devised a method for pinpointing the center of each particle. A beam of parallel light is directed at the slide and the transparent particles act like tiny lenses, focusing the light to a small spot just above each sphere. These tiny spots act as markers for the location of each sphere and are used to note the beginning and ending points of the measurement with a precision about ten times better than can be obtained from microsphere images.

The other method used, scanning electron microscopy, also can involve viewing the particles directly, but once again a special procedure is used by Bureau scientists to ensure an exact measurement. Most scanning electron microscopes move a beam of electrons across the object being examined. The electrons "bounce" off the surface of the object, they are counted by a detector, and an electron intensity picture of the object is constructed on a television monitor. In this project, however, NBS physicist Dr. Gary Hembree is using an instrument that reverses the process: the electron beam is stationary and a single sphere is moved across it. The spheres are mounted on a platform attached to a piezoelectric "pusher." As voltage is applied to the pusher, it expands in tiny increments thereby moving the sample under the beam. The exact distance the sample has been moved is determined with a laser interferometer, an extremely precise instrument that measures distance using intersecting beams of laser light. The result is a scattered electron profile of the particle which can be measured with a resolution of about 15 nanometers.

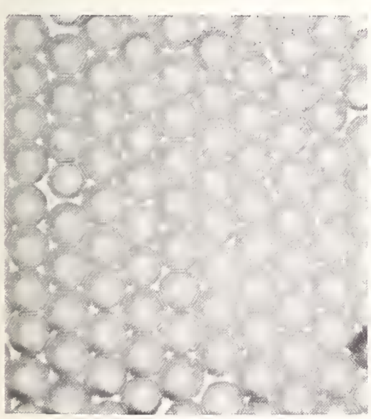
The 0.3- and 1-micrometer particle SRM's, manufactured on Earth, have been certified and are available now for sale. If all goes according to plan, the 10-micrometer space spheres should be ready for sale by early 1985. Proceeds from the sale of the space spheres will be shared by the Bureau and NASA to recover some of the costs of producing and certifying the standard. Meanwhile, through the NBS Research Associate Program, the ASTM will provide the services of Russell C. Obbink to help with the NBS certification process.

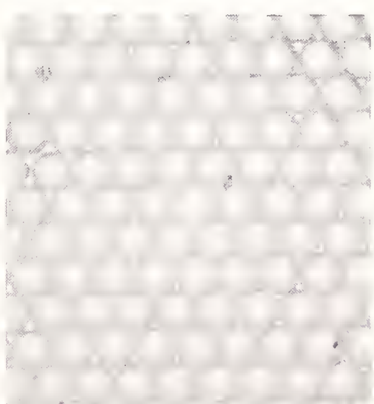
"We make the best measurements we can," says Lettieri, "so that the measurement uncertainty will still be acceptable by the time it gets down to the guy grabbing the flour out of the vat."

Once in the Office of Standard Reference Materials' inventory, the particle standards will join a growing list of other unusual products. So far, the Bureau has produced standard metals and alloys; standard glasses; standard thermometers; standard urban dust, river sediment, and oyster tissue; standard oil; standard computer tapes; and even standard water. Among such a menagerie of wares, spheres from space seem pretty ordinary after all.

(For further information about these or any other SRM's, write or call the Office of Standard Reference Materials, B311 Chemistry Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2045.)

by Gail Porter
Washington, DC, Science Writer





Photomicrograph at left shows 5-micrometer polystyrene spheres made on Earth; 5-micrometer spheres made on the space shuttle are shown in right photomicrograph.

Measurement Methods for a New Industry: Industrial Radiation

In the not-very-distant future, Americans may see startling new products on the grocery shelves: radiation-processed foods.

It may take a while—there are some questions concerning the regulations and economics of this technology—but irradiated fruits, grains, and meats will almost surely turn up in our markets sooner or later. More than 20 foreign countries have already approved the use of at least some "cosmic-processed" or "radappertized" foods.

Depending on the dose, radiation such as gamma rays or x rays can retard the spoilage of fresh fruits, vegetables, and fish. It can be used in place of dangerous chemicals such as ethylene dibromide (EDB) to control insect pests in grains and fruits—it is already used in processing spices—or to kill disease organisms such as salmonellae, campylobacter, and trichinae in meats. At higher doses, radiation treatment will sterilize foods, leading to those long-predicted space-age meats that can sit on a pantry shelf for years without spoiling.

Most of these treatments, however, require a fairly narrow range of irradiation. Too little will not achieve the desired effect, too much may damage the food.

Food preservation is only one of the growing number of uses for "industrial radiation." Gamma rays, x rays, and high-energy electron beams are also being used to sterilize disposable medical devices in hospitals and clinics and to induce useful changes in plastics. Tires, for example, are sometimes irradiated to make the elastomer easier to handle in production, and radiation is used to make dry lubricants out of waste plastic. These industrial uses of radiation are also quite sensitive to dosage, and dosimetry is the most convenient and accurate means of quality control.

As the commercial uses of radiation multiply, researchers at NBS and other federal agencies are developing a number of literally "colorful" techniques to bring accurate measurement to radiation processing. In a way, it all goes back to 1881 and Thomas Griffiths' gatepost. Griffiths' gatepost was as different from other gateposts as night and day. In fact, it was different night and day. It was white during the night and black during the day.

Griffiths' gatepost, which created something of a stir in the chemical literature of the time, had been painted with a zinc-based pigment called lithopone. Lithopone went through a chemical reaction when light fell on it and changed from white to black. What was curious was that the reaction was reversible—when the light source was removed, the compound changed back to white again. Chemists of the day called the phenomenon "phototropy."

The gatepost was a good indicator for telling whether it was night or day, but since better methods were available, nothing much came of it at the time.

About 40 years later, the gatepost and related phenomena came to the attention of Dr. Lyman Chalkley, Jr., a private chemist who was working on a detailed investigation of phototropic substances. Chalkley became a world authority on photochemistry and, in particular, on light-sensitive dyes. In 1964, he went to meet with William McLaughlin, an NBS physicist.

Chalkley had a collection of chemical compounds that would change from clear to colored when they were exposed to ultraviolet radiation, and he wondered if the same thing would happen if they were exposed to x rays. Radiation physics was McLaughlin's speciality.

The first experiments were not promising. "We tried out comparatively low doses of x rays with no discernible effect," McLaughlin recalls, "so I continued exposing the colorless samples to higher doses. It turned out that they not only changed color, but they did it linearly, and the effect was the same at both low and high dose rates."

That is, the color changed at a rate that was constant with the radiation dose, and it did not make any difference whether you exposed the compounds to a high dose rate for a short time or a low dose rate for a long time.

Now when you want to measure something like light or radiation exposure, those are very handy characteristics for your measurement tool. McLaughlin was immediately interested in Chalkley's dyes. Up to that time, there were no visually discernible chemical detectors that changed linearly with high radiation doses.

Over the next several years, McLaughlin and a handful of colleagues, from groups such as the Food and Drug Administration (FDA), the U.S. Army, and the Federal Emergency Management Agency (FEMA), studied the color-changing dyes, which they called "radiochromic leucodyes." (Leukos in Greek means "white," so these are literally "radiation-colored colorless dyes.")

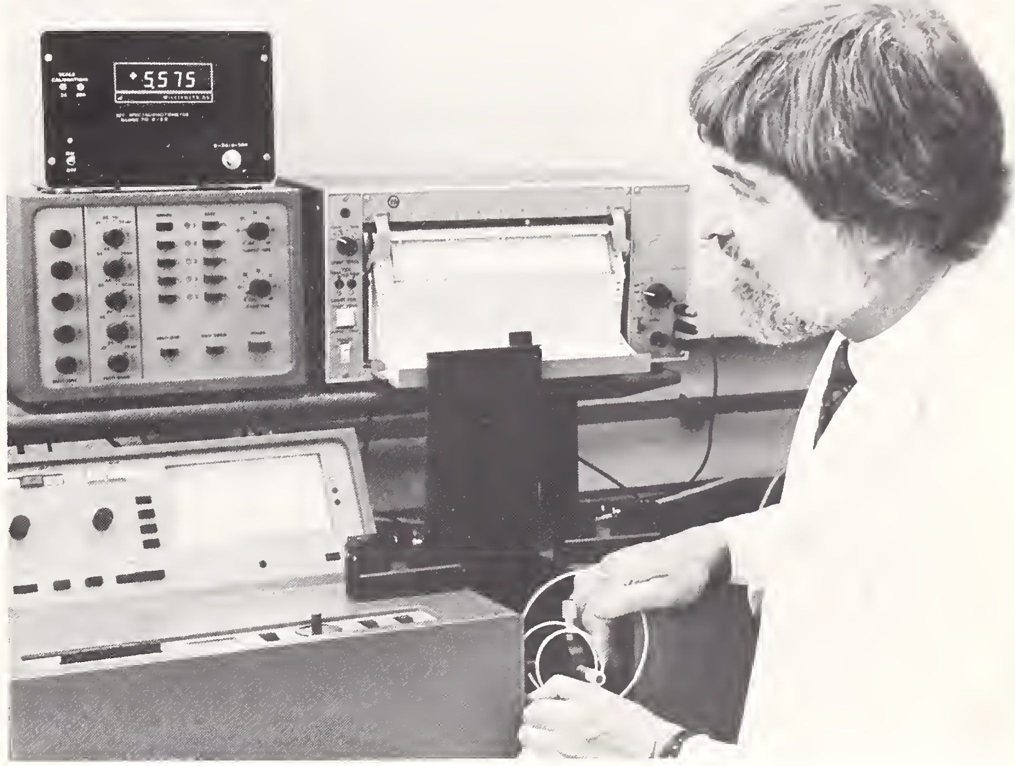
The dyes proved amazingly versatile: they could be used in liquid solutions or mixed into gelatins or plastics. In a chemically neutral medium, the dyes would become colorless again as soon as the radiation source was removed—just like Griffiths' gatepost. In a slightly polar-acid medium, they would stay colored once changed, and the color would deepen with successive exposures to radiation.

McLaughlin and his colleagues developed a number of applications for the radiochromic dyes that are now commonplace. Thin plastic films impregnated with such a dye became industrial dosimeters, used in radiation processes to sterilize hospital equipment or to create plastics with special, radiation-enhanced properties. Specially-designed radiochromic dosimeters were used in defense research to monitor the performance of nuclear weapons.

A particularly elegant application was found in medicine. Physicians trying to calculate the dose of x radiation received by a patient at a particular site in the body have to contend with the fact that when x rays are delivered to an area where two different types of tissue, such as bone and muscle, come together, the radiation scatters in a complex, difficult-to-determine pattern of intensities.

McLaughlin and Harry Levine and Marvin Rosenstein of the Bureau of Radiological Health (part of the FDA) showed that radiochromic plastics could be made with the same x-ray absorbence properties as different types of body tissue. These could be used to construct three-dimensional shapes that mimic the body's response to x rays at complicated tissue interfaces and display the result in color.

Dye dosimeters also could be designed to mimic the radiation

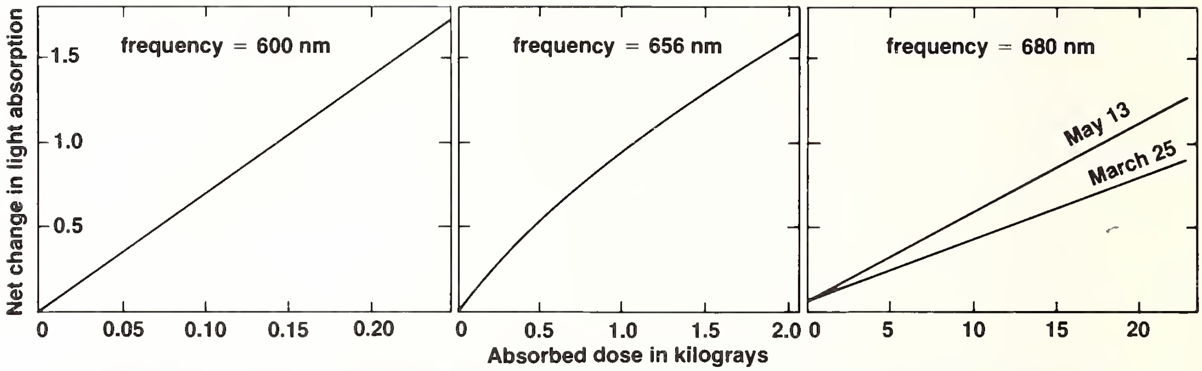


Physicist William McLaughlin studies the use of specially-tailored, radiation-sensitive dyes and fiber optics to make cheap, convenient industrial radiation dosimeters that can be read with a beam of light.

response of other things, such as foodstuffs, avoiding a critical limitation of previous methods of dosimetry.

An annoying problem remained. The depth of the color change was proportional to the radiation dose received, so at low doses, only a small percentage of the molecules in the dosimeter changed color. In order to notice any change, either large doses of radiation or very thick dosimeters were needed.

The film and plastic dosimeters developed up to this point were good for doses of 1,000 rads or more, but they were not very useful for measuring smaller doses. This ruled out a very important range of dosimetry, from the known threshold for biological effects in humans to the average



Three different radiation response curves for a radiochromic dye dosimeter show how the effective range of the dosimeter changes depending on the wavelength of light used to read the dosimeter. Lowest range, 0.01 to 0.25 kilograys, is useful for the elimination of insects in fruits. A good range for increasing the shelf life of meats and vegetables and for killing certain pathogenic organisms such as salmonellae and trichinae is 0.25 to 2 kilograys. Highest range, 2 to 25 kilograys, might be used for the pasteurization and sterilization of fish and meats. The prototype dosimeter used for these measurements showed some tendency to decay over time at higher radiation levels (note curves on chart). Later versions reduced this problem.

lethal dose (roughly, from 10 to 500 rads). McLaughlin, Levine, and two additional colleagues, Carl Siebentritt of FEMA and Stanley Kronenberg of the U.S. Army Communication Electronics Command, considered this new problem.

They calculated that a dye dosimeter of the necessary sensitivity for this range would be about 1 meter thick—not very convenient—and started thinking about other approaches.

The answer, they decided, was to use fiber optics—light pipes. "After all," says Kronenberg, "it is the light path that must be that long, not the dosimeter itself."

A thin plastic tube filled with the proper radiochromic compound made an excellent optical pipe or "waveguide." You could make it as long as you would need and still fit it in a compact space by simply coiling it up.

The first experiments with the waveguide dosimeter brought some surprising results. For instance, the particular dye McLaughlin and the others were using turned blue when irradiated. When they irradiated one of their new optical fiber dosimeters and looked through it, however, the color was red. That required some thought.

The explanation was discovered in the physical theory of light and optics, and in a phenomenon called "anomalous dispersion." This phenomenon carried with it a surprise bonus. Because of its effect on the transmission efficiency of the waveguide at different wavelengths of light, it is possible to control the sensitivity range of the dosimeter simply by selecting the appropriate frequency of light to use in reading it. The same dosimeter can be used to measure radiation doses in ranges from about 1 to 1,000,000 rads, depending on the light source used.

The dyes proved amazingly versatile: they could be used in liquid solutions or mixed into gelatins or plastics.

Various permutations of this long-established, if informal, research group continue working on these amazingly versatile dyes. Very thin fiber-optic dosimeters, they say, could offer a new advance in medical dosimetry—catheter-sized dosimeters that could be slipped into very restricted parts of the body, such as the brain, to measure radiation doses at the actual site of tumors. The U.S. Army is considering the fiber-optic dosimeters for use in "wrist-watch radiacs," a combination digital wrist-watch and radiation monitor for military personnel.

The researchers continue to look for improvements in their dyes as well as the dosimeter materials and techniques. At a recent speaking engagement, Kronenberg stopped before a cup of hollow plastic coffee-stirrers to consider their resemblance to the plastic tubes they were using for waveguides. Before he left, he collected a few samples. After all, you never know where the next good idea will come from.

by Michael Baum
NBS Public Affairs Specialist

Compositional Mapping:

NBS Researchers Take a Glimpse Into the Atomic World

At first glance, aluminum wiring, dental bridges, and semiconductors for computers may not seem to have much in common. At least not on a scale visible to the naked eye. But to a group of NBS analytical chemists, these commodities and many others are playing key roles in a program to advance the science of measurement within atomic dimensions.

To observe this minute region, NBS scientists are probing and analyzing materials with an array of state-of-the-art equipment and determining why, for instance, aluminum wiring connections in electrical outlets can get hot enough to start fires. By creating "compositional maps" with one or several of these analytical instruments, researchers can learn much about aluminum wire and many other materials. They can tell at a glance what processes are occurring chemically in an area of 1 micrometer—about 1/100th the width of a human hair—or less.

Metallurgist Dale Newbury makes an adjustment on the secondary ion mass spectrometry (SIMS) instrument. This instrument allows researchers to map the distribution of elements both on and below a sample's surface.

In existence about 3 years, the Bureau's compositional mapping program is refining measurement techniques that ultimately will be of value to analytical laboratories, manufacturers, universities, and federal agencies, says Dr. Dale E. Newbury, head of the program. He explains that since a vast number of physical and biological processes are controlled by events that take place within atomic dimensions, these maps of elemental distribution can give researchers clues about how to analyze or even to modify these processes. Compositional maps can be valuable, for example, to makers of alloys attempting to create dental bridges that will not corrode or to manufacturers of semiconductor devices trying to figure out why such products sometimes fail.

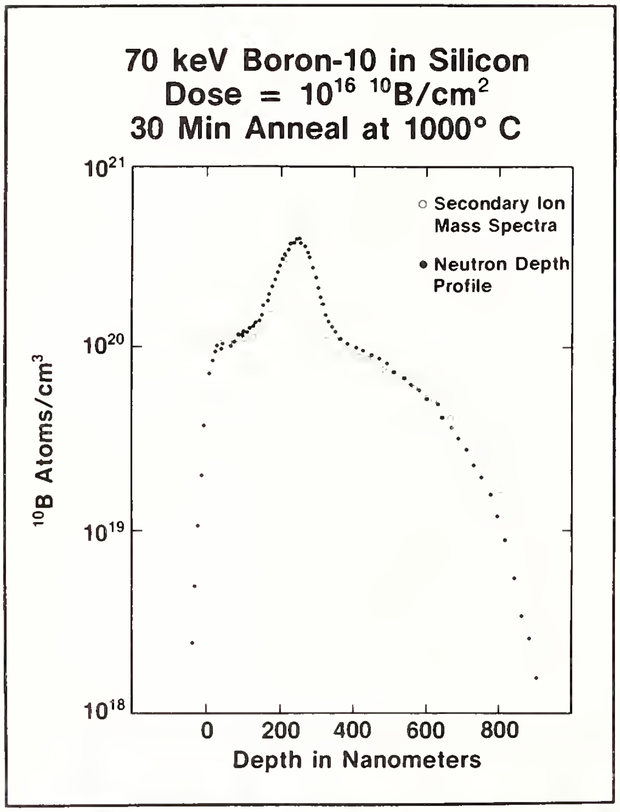
Much like a road map tells travelers which cities are located in a given geographic area, a compositional map tells scientists which elements or compounds are present at any point in a given sample. Some compositional maps are actually photographs that look like aerial maps, while others more closely resemble graphs, with the concentration of elements plotted along one axis and their depth distribution along another.

With a compositional map in hand, researchers can examine not only those elements present on the surface of a sample, but also those in the atom-thin layers under the surface. This can be especially important when evaluating semiconductor samples, because impurities in active regions beneath surface layers may "poison" a device, rendering it ineffective. Knowing the nature of the subsurface elements can give manufacturers the key to modifying device processing for maximum reliability.

Newbury attributes much of the success of the NBS program to the variety of instruments his laboratory is stocked with, some of which are bought, some modified, and one built from scratch. A few of these instruments do their work by using electron beams, one uses ions, and still others operate with photons (light energy). Individually, these instruments are powerful analytical tools, but they are not without shortcomings. Used together, however, the strengths of one machine can compensate for the weaknesses of another.

"No one instrument we have here at NBS is so unusual that we are the only ones who have it," says Newbury. "What makes us unique is that we have such a variety of instruments that complement each other for compositional mapping. This allows us to tackle just about any situation."

The "central workhorse," as Newbury calls it, of the compositional mapping program is the electron probe microanalyzer. This instrument is a scanning electron microscope combined with an x-ray microanalyzer. It allows a highly magnified picture to be made—up to a magnification of 100,000 times—as researchers perform a compositional analysis on the sample. Newbury speaks highly of these instruments: "They are the ones we have the most faith in. We understand them the best, and in a way they are the most powerful—because you can see something and analyze it too, especially on a scale



Left: Two independent compositional mapping techniques, neutron depth profiling (NDP) and secondary ion mass spectrometry (SIMS), were used to produce this map showing the depth distribution of boron in silicon.

Above: An example of a lateral compositional map showing the distribution of oxygen on the surface of a copper alloy. This image was produced by the secondary ion mass spectrometry (SIMS) instrument.

that is of great interest to many practical problems."

It was by using the electron probe microanalyzer that NBS researchers discovered why aluminum wiring fastened loosely at electrical outlets in houses could arc, causing a "glow phenomenon." Temperatures in excess of 1500 °C—enough to melt iron components or to start a fire—were shown to be feasible. By examining compositional maps, researchers found that high-resistance "intermetallic" compounds were being formed through reactions between the aluminum wire and the iron screw holding it in place. The wire in experimental NBS setups was essentially being turned into a heating coil similar to those in toasters. The glow phenomenon, however, was shown to be present only where the aluminum wire was connected loosely. Tight connections generated very little heat.

While the electron probe microanalyzer is considered an excellent tool for analyzing samples about 1 micrometer in size, NBS scientists sometimes need a machine that will image and analyze a much smaller realm for compositional maps. In these instances, researchers turn to the analytical electron microscope, or AEM. With this instrument, it is possible to view and analyze an area 10 billionths of a meter—or about 30 atom diameters—in size. And while it uses the same technology, electron beams, as the electron probe microanalyzer, the AEM gives an image with much higher resolution and thus is more suited for analyzing tiny airborne particles. (The electron probe instrument, on the other hand, works best with solid specimens like aluminum wire.)

The shortcomings of the AEM—it cannot, for example, easily analyze light elements such as boron, oxygen, and carbon—are overcome at NBS by using a laser microprobe mass analyzer (LAMMA). With this instrument, researchers can identify any element in a sample.

NBS is putting the AEM/LAMMA combination to use in a cooperative program with the University of Maryland to study the "Arctic Haze," a dark cloud that hangs over the North Pole. At NBS, researchers are trying to determine where the haze comes from by analyzing single particles and drawing compositional maps. Some scientists in the past have guessed that the haze comes from coal power plants in Europe and Asia, but the NBS/Maryland research is expected to give some of the best information available on the haze's origin.

While the Bureau's compositional mapping program has made some important measurement advances, Newbury says there is room for improvement. For example, while researchers can identify a molecule in a sample, they hope to develop techniques to quantify them.

But for now, whether NBS researchers are working on improving compositional mapping instruments or interpreting the results from those already in use, the program continues to forge new ground in understanding what goes on at the atomic level of processes.

by John Henkel
NBS Public Affairs Specialist

Tools of the NBS Compositional Mapping Program

In the area of compositional mapping, NBS is unique in that it has a full range of analytical equipment at one geographic location. While some of these instruments have shortcomings, NBS researchers often use them in tandem to compensate for weaknesses and increase measurement accuracy. Instruments are either electron, photon, ion, or neutron beam analyzers. Brief descriptions follow:

Electron probe microanalyzer—An electron beam technique that combines a scanning electron microscope and an x-ray microanalyzer, this instrument is normally used for preliminary, nondestructive analyses of solid specimens such as aluminum wire. It allows a photograph up to 100,000 times in magnification to be made and a compositional analysis to be performed within an area of 1 micrometer—about 1/100th the width of a human hair—or more. The technology for these instruments dates back to the late 1940's.

Analytical electron microscope (AEM)—Much more elaborate in its analyzing capabilities, this electron beam device allows an image up to 500,000 times in magnification to be viewed and an analysis within 10 billionths of a meter—about 30 atom diameters in size—to be made. A nondestructive technique, the AEM is normally the instrument chosen for particle analysis because of its higher resolution capabilities. Though it gives an illuminating image of the sample, the AEM cannot give good quantitative analyses of light elements such as lithium, boron, oxygen, or carbon. And the AEM is useless when trying to measure the different types of atoms of a particular element (isotopes), which among other things can give scientists clues about the age of a specimen.

Laser microprobe mass analyzer (LAMMA)—When NBS researchers want a complete analysis of elements, especially within particles, but do not mind if the sample is destroyed, they use the LAMMA. This photon-energy instrument works by concentrating a beam of light at a 1-micrometer target in a sample, destroying the specimen by evaporation. In the process, charged ions are created from some of the sample's atoms. These ions are aimed into a tube-like device, and since all the ions are created at the same instant, they are accelerated simultaneously. But because ions of different elements have varying masses, they are accelerated at different velocities, so the lightest ion will get to the end of the tube first. By examining a readout from the LAMMA, researchers can tell which elements are in the sample, and how much is there.

Secondary ion mass spectrometry (SIMS) instrument—Known commonly as an ion microscope, the SIMS instrument allows NBS researchers to map the distribution of elements both on and below a sample's surface. While literally sputtering away the atom layers, much like peeling an onion, the SIMS instrument takes a series of stop-action pictures of each layer being analyzed. Researchers can record the data either photographically or by storing it in a computer where this data can be enhanced for better interpretation. SIMS, by nature of its sputtering action, destroys the sample.

Neutron depth profiling (NDP)—This technique is often used when researchers want the same kind of depth distribution information the SIMS instrument provides, but do not want to destroy the sample. Using NBS' 20-megawatt reactor to produce a neutron beam, Bureau researchers have to date most often applied NDP in the analysis of semiconductor samples. NDP, however, works only on a few elements such as helium, lithium, boron, and nitrogen. But NDP is valuable because it provides a reference method which can be used to calibrate other techniques such as SIMS.

Laser Raman microprobe—Built from scratch at NBS several years ago, this device allows researchers to analyze the compounds present in samples. Other instruments used in the program are best suited for detecting elements. Before this invention, Raman instruments could be used only on fairly large samples—1 millimeter or larger. What NBS scientists did was to create an instrument that could profile areas down to 1 micrometer in size. And while the Bureau's Raman instrument can show the presence of some compounds, it cannot at present show how much of a compound is in a sample.

MEASUREMENT SYSTEMS AND METHODS FOR OPTICAL FIBERS

*Chamberlain, G.E., Day, C.W., Franzen, D.L., et al., **Optical Fiber Characterization—Volume 2**, Natl. Bur. Stand. (U.S.), NBS Spec. Pub. 637-2, 234 pages (October 1983). Order by stock no. SP 637-2 from the National Bureau of Standards, Division 360.2, Boulder, CO 80303, $15 prepaid.*

NBS fiber optics measurement systems and methods are described in detail in this hardbound book. It covers measurements of attenuation, bandwidth (frequency-domain), and far-field/near-field radiation patterns, plus a glossary of fiber optics terms and definitions. It supplements an earlier publication (SP 637-1) on the measurement of optical fiber backscatter, time-domain bandwidth, and index profile, which is also available from the same address for $15 prepaid.

CENTER FOR FIRE RESEARCH GRANTS AND IN-HOUSE PROGRAMS

*Cherry, S.M., editor, **Summaries of Center for Fire Research Grants and In-House Programs—1983**, Natl. Bur. Stand. (U.S.), NBSIR 83-2800, 156 pages (December 1983). Order by stock no. PB 84-155340 from NTIS, $16 prepaid.*

This publication contains one- and two-page abstracts of grants and contracts for fire research sponsored by the NBS Center for Fire Research. In addition, the Center's internal research programs are described.

NEW NBS STANDARD REFERENCE MATERIALS CATALOG

*Hudson, C.H., editor, **NBS Standard Reference Materials Catalog 1984-1985**, Natl. Bur. Stand. (U.S.), NBS Spec. Pub. 260, 174 pages (February 1984). Order by stock no. SP 260 from the Office of Standard Reference Materials, B311 Chemistry Building, National Bureau of Standards, Gaithersburg, MD 20899, telephone 301/921-2045.*

This new catalog lists more than 900 Standard Reference Materials (SRM's) available from NBS. For more than 75 years, NBS has provided SRM's to scientific, industrial, and commercial users throughout the world. They are used to help improve measurement accuracy by providing a way to calibrate instruments. SRM's, which are well-characterized materials with specific chemical or physical properties certified by NBS, include such items as cements, ores, metals, glasses, plastics, foods, and environmental and clinical reference materials. The catalog's format provides quick access to material description, certified characterization, unit size, and type.

LIQUEFIED NATURAL GAS DENSITIES

*Haynes, W.M., McCarty, R.D., and Hiza, M.J., **Liquefied Natural Gas Densities: Summary of Research Programs at the National Bureau of Standards**, Natl. Bur. Stand. (U.S.), NBS Monograph 172, 240 pages (October 1983). Order by stock no. 003-003-02528-3 from GPO, $6.50 prepaid.*

Knowing the densities of liquefied natural gas (LNG) and its components is crucial for those involved in the production, transport, use, and, especially, the sale of this important commodity. Domestic and international trade in LNG amounts to billions of dollars per year, and accurate knowledge of its properties, especially density, is essential to equity in trade and efficient processing and utilization. This publication provides results of a 10-year program to develop mathematical models, instrumentation, and an accurate database for LNG density. It also reprints 14 original papers on LNG density published by NBS researchers since 1972 in a variety of media.

CRITERIA FOR STORING PAPER RECORDS

*Mathey, R.G., Faison, T.K., and Silberstein, S., **Air Quality Criteria for Storage of Paper-Based Archival Records**, Natl. Bur. Stand. (U.S.), NBSIR 83-2795, 51 pages (November 1983). Order by stock no. PB 84-135607 from NTIS, $13 prepaid.*

To save time and money, many organizations now preserve records on microfilm and discard the original paper materials. But some records, such as historical documents or valuable books, need to be preserved permanently in ideal storage conditions. When storing these archival documents, factors such as temperature, humidity, and air pollutants need to be controlled. A study by the NBS Center for Building Technology on the air quality in the National Archives Building in Washington, D.C., describes damage that may otherwise occur, and proposes criteria for setting environmental conditions. Examples of air quality criteria now used by various libraries and museums also are given. Although this study was conducted to improve the air quality in a particular building, it should be useful in the design or modification of other facilities used to store archival materials.

AN OVERVIEW OF ARTIFICIAL INTELLIGENCE

*Gevarter, W.B., **An Overview of Artificial Intelligence and Robotics: Volume 1—Artificial Intelligence, Part A—the Core Ingredients**, Natl. Bur. Stand. (U.S.), NBSIR 83-2799, 66 pages (January 1984). Order by stock no. PB 84-178037 -A04 (paper) or -A01 (fiche) from NTIS, $10 (paper) or $4.50 (fiche).*

NBS, in cooperation with the National Aeronautics and Space Administration (NASA), has published a new overview to the field of artificial intelligence (AI). The overview, by Dr. William B. Gevarter of NASA, discusses the nature of AI and its history, techniques, and applications. It also lists the principal organizations, both foreign and domestic, now pursuing AI research. The two other parts of this study were published by NASA and are available from NTIS: ***Part B—Fundamental Application Areas*** (NTIS #N84-10834, $13 paper/$4.50 fiche) and ***Part C—Basic AI Topics*** (NTIS #N84-14805, $10 paper/$4.50 fiche).

TEXT ON EXPERIMENTATION AND MEASUREMENT

*Youden, W.J., **Experimentation and Measurement**, Natl. Bur. Stand. (U.S.), NBS Spec. Pub. 672, 127 pages (March 1984). Order by stock no. 003-003-02575-5 from GPO, $3.75 prepaid.*

NBS has republished a popular text to introduce science students to the role of elementary statistics in the design and interpretation of experiments. It was first published in 1962 as part of a series of books developed and produced by the National Science Teacher's Association, and has been out of print for several years. In short, essay-like chapters, Youden takes the student from a general discussion of the importance of measurements in science, through the harsh fact of the existence of experimental error, to the use of statistics to bring some order to chaos. Along the way he invokes examples from everyday life and practical situations in science and engineering. Youden, who died in 1971, was a recognized master in the field of the statistical design of experiments.

ECONOMIC MODEL ASSESSES BENEFITS OF IMPROVED TEST ACCURACY

*Weber, S.F., and Hillstrom, A.P., **Economic Model of Calibration Improvements for Automatic Test Equipment**, Natl. Bur. Stand. (U.S.), NBS Spec. Pub. 673, 84 pages (April 1984). Order by stock no. 003-003-02580-1 from GPO, $3.25 prepaid.*

NBS has developed an economic model to calibrate the benefits of improving the quality of measurements made in maintenance or production testing programs. The model will assist managers in assessing the value of improving the accuracy of electronic test equipment, especially "automatic test equipment" (ATE). NBS researchers say it also can be applied easily to many other types of testing situations. Quality assurance managers must take into account the fact that ATE, like all test equipment, occasionally will make a mistake and either reject a good unit or accept a faulty unit. Rejecting or retesting good products is obviously expensive, but accepting bad products can be even more costly, particularly if lives depend on the proper functioning of the product. The model can be used to optimize policies for procurement of new test equipment, for maintenance and calibration of existing test equipment, and for setting test specifications to achieve the proper balance between "consumer's loss" and "producer's loss."

COMPUTER SECURITY GUIDELINE

***Guideline for Computer Security Certification and Accreditation**, Natl. Bur. Stand. (U.S.), NBS FIPS-PUB-102, 95 pages (September 1983). Order by title and stock no. FIPS-PUB-102 from NTIS, $11.50 prepaid.*

Probably as important as having a general computer security program is being assured it meets an organization's specific security requirements. The Institute for Computer Sciences and Technology at NBS has developed a guide designed to give managers a structured way of determining whether their computer security safeguards are adequate for their individual needs. This report is designed especially to help protect highly sensitive computer systems and data, but it can be used for less sensitive systems as well. This Federal Information Processing Standards publication details steps on how to establish and carry out a certification and accreditation program. It also discusses evaluation techniques which can be used, including risk analysis; validation, verification, and testing; EDP audit; and security safeguard evaluation. A companion document, ***Overview of Computer Security Certification and Accreditation***, is available through GPO for $1.50 prepaid. Order by stock no. 003-003-02567-4.

SUPERCRITICAL FLUID EXTRACTION

*Fly, J.F., and Baker, J.K., **A Review of Supercritical Fluid Extraction**, Natl. Bur. Stand. (U.S.), NBS Tech. Note 1070, 77 pages (December 1983). Order by stock no. 003-003-02537-2 from GPO, $4.50 prepaid.*

The use of dense gases in a supercritical state as solvents in chemical extractions and separations has grown rapidly in the last 10 years as an alternative to liquid solvents and distillation methods. Supercritical fluid extraction (SFE) offers improved thermal efficiency in some cases, avoids thermal degradation of extracted components in other systems, and substitutes non-toxic solvents for toxic ones in certain food and drug processes. SFE also has applications as an analytical tool and for thermophysical properties measurements. This review summarizes the physical phenomena and describes several applications of SFE in the energy and chemical industries (coal conversion, de-ashing, de-caffeination) and in analysis and measurements.

ORDERING INFORMATION

To order publications from NTIS, send request with payment to: National Technical Information Service, Springfield, VA 22161. Publications can be ordered from GPO by mailing order with payment to: Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. ■

CONFERENCE CALENDAR

Winter Simulation Conference, Sheraton Dallas Hotel, Dallas, TX

November 28-30, 1984

The 1984 Winter Simulation Conference will feature papers, tutorials, state-of-the-art review sessions, and panel discussions on discrete and combined (discrete continuous) simulation. The following topics will be discussed: distributed simulation, offshore technology, manufacturing, environmental systems, mini and micro applications, graphic applications, health care systems, transportation, energy and petroleum systems, communications, military systems, aerospace applications, and planning scheduling. Sponsored by the Association for Computing Machinery, the Institute of Electrical and Electronics Engineers, the Institute of Industrial Engineers, NBS, the Operations Research Society of America, the Society for Computer Simulation, and the Institute of Management Sciences. Contact: Patsy Saunders, A1013 Administration Building, NBS, Gaithersburg, MD 20899, 301/921-3132.

Computer Networking Symposium, NBS, Gaithersburg, MD

December 12, 1984

This symposium will highlight discussions of the design, selection, performance, and implementation of current and soon-to-be-available networking systems. Papers are being solicited on such topics as long-haul networks, PBX systems, satellite systems, video systems, electronic mail, teleconferencing, network testing, network procurement, and videotext. Sponsored by the Institute of Electrical and Electronics Engineers Computer Society and NBS. Contact: Robert Rosenthal, B226 Technology Building, NBS, Gaithersburg, MD 20899, 301/921-3516.

Eighth Conference on Materials for Coal Conversion Utilization, NBS, Gaithersburg, MD

February 27-March 1, 1985

The latest materials research and development information pertinent to fossil energy systems will be presented at the Eighth Conference on Materials for Coal Conversion and Utilization. The systems to be discussed include conventional and advanced coal-fired power plants, coal gasification and liquefaction, heat engines and heat recovery, and fuel cells. The conference will broadly cover both metal and ceramic applications. Sponsored by NBS, the Electric Power Research Institute, the Department of Energy, and the Gas Research Institute. Contact: Samuel J. Schneider, A257 Materials Building, NBS, Gaithersburg, MD 20899, 301/921-2845.

The Mechanical Failures Prevention Group (MFPG) Symposium, NBS, Gaithersburg, MD

April 16-18, 1985

This MFPG symposium will attempt to improve communications among the people who are responsible for reducing mechanical failures in weapons systems and supporting defense equipment. Participants will be given an opportunity to identify new and advanced techniques for mechanical failure detection. These technologies will help Department of Defense (DoD) design and test engineers, their industrial suppliers, and DoD consultants to improve the readiness and reliability of military weapons, support equipment, and structures. Sponsored by NBS, the Office of Naval Research, and the Army Materials Mechanics Research Center. Contact: Dr. James Early, A153 Materials Building, NBS, Gaithersburg, MD 20899, 301/921-2976.

OM 85 Topical Conference on Basic Properties of Optical Materials, NBS, Gaithersburg, MD

May 7-9, 1985

The use of optical materials in advanced applications such as optical signal processing, optical computing, integrated optics, optical coatings, optical domes, and laser windows is placing increasingly stringent requirements on material performance. The purpose of this NBS conference is to bring together researchers from industry, academia, and government to discuss the physical and structural properties of optical materials as they affect performance. The scope of the conference will include the measurement and theory of basic properties of optical materials in bulk and in thin film form and the dependence of these properties on atomic structure, morphological structure, impurity content, and inhomogeneity. Sponsored by NBS, the Air Force Office of Scientific Research, and the Office of Naval Research. Contact: Dr. Albert Feldman, B328 Materials Building, NBS, Gaithersburg, MD 20899, 301/921-2817.

International Conference on Biologically Induced Corrosion, NBS, Gaithersburg, MD

June 10-12, 1985

This conference will focus on mechanisms, case histories, and experimental methods of and remedial measures for biologically induced corrosion in both natural and artificial environments. Special emphasis will be placed on corrosion mechanisms and on establishing the causative links between the simultaneous observations of corrosion and the presence of microorganisms. The conference will also define topics for further research. Sponsored by the National Association of Corrosion Engineers and NBS. Contact: Dr. Warren Iverson, A331 Materials Building, NBS, Gaithersburg, MD 20899, 301/921-2953. ■

The National Bureau of Standards[1] was established by an act of Congress on March 3, 1901. The Bureau's overall goal is to strengthen and advance the nation's science and technology and facilitate their effective application for public benefit. To this end, the Bureau conducts research and provides: (1) a basis for the nation's physical measurement system, (2) scientific and technological services for industry and government, (3) a technical basis for equity in trade, and (4) technical services to promote public safety. The Bureau's technical work is performed by the National Measurement Laboratory, the National Engineering Laboratory, the Institute for Computer Sciences and Technology, and the Center for Materials Science.

The National Measurement Laboratory

Provides the national system of physical and chemical 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; provides advisory and research services to other Government agencies; conducts physical and chemical research; develops, produces, and distributes Standard Reference Materials; and provides calibration services. The Laboratory consists of the following centers:

- Basic Standards[2]
- Radiation Research
- Chemical Physics
- Analytical Chemistry

The National Engineering Laboratory

Provides technology and technical services to the public and private sectors to address national needs and to solve national problems; conducts research in engineering and applied science in support of these efforts; builds and maintains competence in the necessary disciplines required to carry out this research and technical service; develops engineering data and measurement capabilities; provides engineering measurement traceability services; develops test methods and proposes engineering standards and code changes; develops and proposes new engineering practices; and develops and improves mechanisms to transfer results of its research to the ultimate user. The Laboratory consists of the following centers:

- Applied Mathematics
- Electronics and Electrical Engineering[2]
- Manufacturing Engineering
- Building Technology
- Fire Research
- Chemical Engineering[2]

The Institute for Computer Sciences and Technology

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 (40 U.S.C. 759), relevant Executive Orders, and other directives; carries out this mission by managing the Federal Information Processing Standards Program, developing Federal ADP standards guidelines, and managing Federal participation in ADP voluntary standardization activities; provides scientific and technological advisory services and assistance to Federal agencies; and provides the technical foundation for computer-related policies of the Federal Government. The Institute consists of the following centers:

- Programming Science and Technology
- Computer Systems Engineering

The Center for Materials Science

Conducts research and provides measurements, data, standards, reference materials, quantitative understanding and other technical information fundamental to the processing, structure, properties and performance of materials; addresses the scientific basis for new advanced materials technologies; plans research around cross-country scientific themes such as nondestructive evaluation and phase diagram development; oversees Bureau-wide technical programs in nuclear reactor radiation research and nondestructive evaluation; and broadly disseminates generic technical information resulting from its programs. The Center consists of the following Divisions:

- Inorganic Materials
- Fracture and Deformation[3]
- Polymers
- Metallurgy
- Reactor Radiation

[1] Headquarters and Laboratories at Gaithersburg, MD, unless otherwise noted; mailing address Gaithersburg, MD 20899.
[2] Some divisions within the center are located at Boulder, CO 80303.
[3] Located at Boulder, CO, with some elements at Gaithersburg, MD.

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