NATIONAL BUREAU OF STANDARDS

NBS Research Reports

U.S. DEPARTMENT OF COMMERCE
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NBS SPECIAL PUBLICATION 680-4

Cover photo: Research chemist Susan F. Stone prepares a homogenized human liver sample for chemical analysis in the clean laboratory of the NBS environmental specimen bank, which is being used to preserve hundreds of samples of human tissue and environmental specimens. See page 22.

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Malcolm Baldrige, Secretary

National Bureau of Standards
Ernest Ambler, Director

National Bureau of Standards
Gaithersburg, MD 20899
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National Bureau of Standards
Boulder, CO 80303
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Sharon Shaffer, Editor
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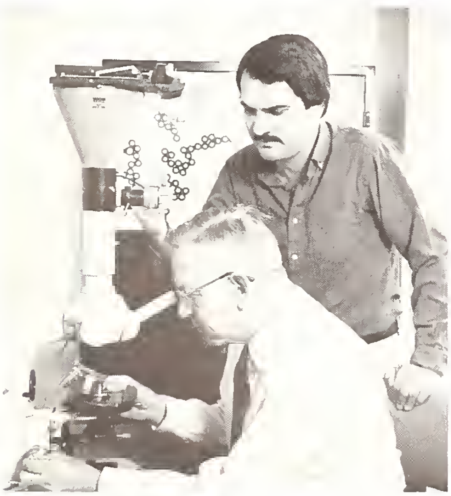
RESEARCH UPDATE

FIRST COMMERCIAL SPACE-MADE PRODUCTS SOLD

The first sales of a product manufactured in space were announced July 17 by NBS. Billions of tiny polystyrene spheres made aboard a NASA space shuttle flight are being offered as an NBS Standard Reference Material. "They will be used to improve microscopic measurements made throughout the economy in electronics, medicine, and other high-technology areas," NBS Director Ernest Ambler said. The space-made spheres, each 10 micrometers (1/2500 of an inch) in diameter, are being purchased by producers of finely ground powder products as well as by technologists who monitor environmental particulate pollution from industrial and chemical plants. They also will be used by medical researchers who calibrate instruments to count blood cells and measure their shape and to perform a wide variety of diagnostic measurements.



Physicists Thomas R. Lettieri and Arie W. Hartman (seated) are using a high-resolution microscope to photograph strings of 10-micrometer polystyrene spheres on glass slides. They will measure the spacings between dots of light that optically mark the center of each sphere to determine the average size and quality of the space-made particles.

The billions of spheres were produced using a chemical process developed for NASA by Lehigh University. When ASTM learned about the high quality of the material, this group asked that NBS measure the spheres and make them available to the public as a measurement standard. Each unit is available in a 5-milliliter vial that contains about 30 million spheres. They are in a 0.4 percent concentration by weight; the remainder is water. The price of Standard Reference Material 1960, 10-Micrometer Polystyrene Spheres, is $384 per unit. Order from the Office of Standard Reference Materials, B311 Chemistry Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2045.

PULSED-ELECTRON 4-MeV VAN DE GRAAFF SOURCE AVAILABLE

NBS has converted its 4-MeV electron Van De Graaff accelerator to provide pulsed electron beams in addition to continuous beams. The pulsed beams are useful for research in pulsed radiolysis; chemical kinetics; radiation dosimetry; and atomic, molecular, and nuclear physics. They have energies between 1.5 and 3 MeV; pulse widths of 5, 15, 50, 500, 1500, and 5000 nanoseconds; and a maximum beam current of approximately 0.5 ampere. Access to the electron beam itself is available through Kapton, aluminum, or titanium windows. In addition, a number of bremsstrahlung targets for producing photon spectra are also available. The facility is open to outside users. Interested researchers should write or call Dr. Charles Dick, C216 Radiation Physics Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2201.

CALIBRATION SERVICE FOR CONDUCTIVITY STANDARDS INTRODUCED

NBS is offering a new special test service for the calibration of electrical conductivity standards for eddy current conductivity meters. Such meters are used widely in the aerospace and automotive industries for testing and sorting nonferrous metals and alloys. The new service provides conductivity calibrations for standards ranging from 15 to 100 percent IACS (International Annealed Copper Standard), measured at frequencies between 10 and 100 kHz. Special arrangements can be made for calibrations at user-specified frequencies. Calibrations are made with an accuracy of 0.15 percent of stated value and turnaround time is approximately 30 days. The fee for a single calibration is approximately $100, and standards to be calibrated must meet certain geometrical specifications. For further information, write or call George Free, B146 Metrology Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2715.

NEW GENERATION OF GRAVITY METERS DEVELOPED

Scientists at the Joint Institute for Laboratory Astrophysics have developed a new generation of portable absolute gravity meters which have been designed for geodetic, geophysical, geological, tidal, and tectonic studies. The instruments use the free fall method and consist of four parts: a drag-free dropping chamber, a long-period isolation device, a stabilized laser, and the necessary timing electronics. Special emphasis was placed on making this latest group of gravity meters durable and easy to use. A copy of a paper describing the new gravity meters is available from Fred McGehan, Division 360.2, National Bureau of Standards, Boulder, CO 80303, 303/497-3246.

HOT BOX TESTS ENERGY PERFORMANCE OF WALLS

Full-scale wall sections are being tested in NBS' new "calibrated hot box" to better understand how heat, air, and moisture are transferred through them. The tests are also being used in the development of standard test methods that industry can use to evaluate the energy performance of different types of wall systems under varying climate conditions. Currently, these methods do not exist.

Moreover, NBS researchers plan to put the facility to work developing and verifying mathematical models that building product manufacturers and designers can use to predict thermal performance.

Although there are about two dozen other hot boxes in the country, this one is unique because of its size and measurement precision and for the special research that will be conducted using the facility. The NBS hot box can measure simultaneously heat, air, and moisture flow in full-scale building wall sections up to 10 feet high by 15 feet wide.

Though the facility is not designed as a testing service, the NBS researchers look forward to working with industry on unique problems. Inquiries regarding the facility should be directed to Tom Faison, B114 Building Research Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-3501.

ULTRASENSITIVE EDDY CURRENT FLAW DETECTOR DEVELOPED

NBS researchers have developed an extremely sensitive tool for characterizing materials and detecting flaws in conducting surfaces. The novel instrument uses a superconducting quantum interference device (SQUID) as an amplifier to detect small perturbations of the electromagnetic field induced on the surface by an eddy current probe. Current versions of the instrument are about 10,000 times more sensitive than similar eddy current probes without SQUID's. The increased sensitivity does not allow detection of flaws 10,000 times smaller, but it offers the option of increasing the spatial resolution (size and location of flaws) and signal-to-noise ratio (allowing operation in noisier environments.) While the superconducting amplifier must be cooled with liquid helium, newly developed techniques allow the probe and materials under test to remain at room temperature. For more details, contact John C. Moulder, Division 430.0, National Bureau of Standards, Boulder, CO 80303, 303/497-3937.

DATABASE AVAILABLE ON BEHAVIOR OF SALTS IN SOLUTIONS

Industrial and chemical engineers—including battery manufacturers, producers of steam power, environmentalists and oceanographers, users of soda and potash for fertilizers, and others concerned with salts—will be interested in a new NBS computerized database for quantitatively determining the physical and chemical behavior of ions in solutions. GAMPHI—A Database of Activity and Osmotic Coefficients for Aqueous Electrolyte Solutions—written in Fortran 77, contains information for 350 binary aqueous electrolyte solutions at 298.15 K. The computer codes can be used interactively to retrieve the data at a terminal, or they can be incorporated with in-house programs to calculate values for specified concentrations. The computerized database may be purchased for $200 from the Office of Standard Reference Data, A323 Physics Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2228.

NEW REFERENCE MATERIALS DEVELOPED FOR MICROANALYSIS

Analytical laboratories seeking to ensure the accuracy of microprobe analyses and instruments may do so with a series of five Standard Reference Materials (SRM's) now available from NBS. Designed for use with techniques such as electron-probe microanalysis and secondary-ion mass spectrometry, the SRM's are in the form of 20-milliliter-long glass rods. Each SRM in the new series has three different rods: one with a base composition and each of the other two doped with small amounts of additional elements.

The SRM's, Glasses for Microchemical Analysis (SRM's 1871 through 1875), are available for $196 each from the Office of Standard Reference Materials, B311 Chemistry Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2045.

MAP FOR SPECTROPHOTOMETRIC TRANSMITTANCE BEGUN

NBS has established a new Measurement Assurance Program (MAP) for laboratories measuring spectral transmittance. The program makes it possible to check the absolute calibration of spectrophotometers against the NBS scale over a transmittance range of 0.92 to 0.001, as well as the wavelength accuracy of the spectrophotometers. MAP's are special calibration programs developed by NBS that make it possible to evaluate the entire measurement system and procedures of a participating laboratory, rather than simply the instruments used by that laboratory. The cost of the spectrophotometric transmittance MAP is $1,700. Details of the program are available from Kenneth Eckerle, B306 Metrology Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2791.

TITANIUM DENTAL CROWNS TESTED AS ALTERNATIVE TO ALLOYS

Titanium could offer dentists a practical alternative for gold and imported metals currently used in dental crowns if the material proves itself in clinical studies now beginning at NBS. The first precision casting of a pure titanium dental crown in the United States was made recently in the dental laboratories of the Paffenbarger Research Center (PRC) of the American Dental Association Health Foundation at NBS. "If titanium performs as well as traditional gold alloys, it could replace the more expensive material for dental restorations, as well as the use of imported nickel, cobalt, and chromium for dental appliances," says Dr. Nelson W. Rupp, associate director of PRC and the first volunteer patient to receive a titanium dental restoration. Rupp's crown and those being made for other volunteer patients will be observed by PRC/NBS scientists for at least 2 years.

POTENTIAL SAVINGS IN AUTO INDUSTRY FRACTURE CONTROL

Economic studies by NBS of the costs of fracture of structural materials indicate that about $3 billion a year (out of some $35 billion total national fracture costs) could be saved in the automobile manufacturing industry alone. NBS is joining with Ford Motor Company to study methods of realizing these savings through modifications of design, materials selection, and manufacturing processes. The study will consider the effects and capital requirements of database development in support of revised and updated codes and standards, of development of improved materials that have less mechanical property variability, and of advanced inspection systems and automated manufacturing equipment.

The study will be carried out by NBS' Dr. Bruce Christ, who will spend the next year at Ford as a Commerce Department Science and Technology Fellow, working with Ford's economists, database experts, technical experts, and policymakers. The methodology developed in the study will be published for use throughout American industry. For more information, write or call Dr. Bruce Christ, Research Lab/Room 5 2065, Ford Research and Engineering Center, 2000 Rotunda Drive, P.O. Box 2053, Dearborn, MI 48121-2053, 313/323-1423, or Dr. Richard Reed, Division 430.0, National Bureau of Standards, Boulder, CO 80303, 303/497-3870.

MEASUREMENTS REDUCE LIMIT FOR ANISOTROPY OF SPACE

Is there a preferred reference frame in space? According to Einstein's Theory of General Relativity, the answer is "no," and physicists at NBS have confirmed this with an experiment based on atomic clocks that is 300 times more sensitive than any previous measurement. In a test of spatial anisotropy, NBS scientists made comparisons between a hydrogen maser atomic clock and a clock based on laser-cooled beryllium ions stored in a magnetic trap. If there were a preferred direction in space, the hydrogen maser would be relatively unaffected while the rate of the ion-based clock would be dependent on its orientation in space. The experiments, conducted by Drs. John Prestage, John Bollinger, Wayne Itano, and Dave Wineland, showed no dependence, within 100 mHz, of the relative clock rates on their orientation with respect to the sun or fixed stars. This represents about a 300-fold improvement over the 1961 Hughes et al./Drever experiments based on careful nuclear magnetic resonance measurements.

MATERIALS AIMED AT BOOSTING ACCURACY OF LEAD-IN-BLOOD TESTS

To improve the reliability of blood tests for determining long-term exposure to lead, NBS has developed a Standard Reference Material (SRM) for calibrating the laboratory instruments that measure minute amounts of lead in blood. Wide-ranging results—some in error by as much as 200 percent—have been obtained in past studies by NBS and other agencies when blood samples with known lead concentrations were sent to various clinical laboratories for analysis. Though analyses have improved in recent years due to refinements in technology and increased quality control, there is still a need for a lead-in-blood standard as a reference for checking instrument accuracy and analytical methods. The new SRM should fill this need. Each unit of the SRM contains four bottles of varying lead concentrations in porcine blood; it sells for $104 per unit. Lead concentrations are 5.7, 30.5, 49.4, and 73.2 micrograms per deciliter. Order from the Office of Standard Reference Materials, B311 Chemistry Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2045.

OHIO WEIGHTS AND MEASURES LAB AUTHORIZED TO TEST DEVICES

The Ohio State Weights and Measures Laboratory is the first state laboratory to be authorized by NBS to test weighing and measuring devices under the new National Type Evaluation Program (NTEP). The Ohio Department of Agriculture requested the authorization after expanding its Columbus facility to meet criteria and test procedures developed by the National Conference on Weights and Measures (NCWM) for evaluating electronic commercial weighing and measuring devices. The Ohio laboratory contains an environmental chamber and specialized equipment for testing the shielding on equipment against unwanted electronic interferences such as the effects of CB radio signals on highway truck scales. NTEP was established in cooperation between NBS and NCWM to offer manufacturers a one-time evaluation of new weighing and measuring devices by either NBS or one of the states that will be accepted by all of the others, thereby eliminating duplicate tests by each jurisdiction.

NOVEL INVENTION AIMED AT BETTERING FLOW MEASUREMENTS

Two NBS researchers have been granted a patent for inventing an electronic circuit that can be used in a flowmeter to determine, among other things, the volume flowrate or steam flowing in a pipe. James E. Potzick and Dr. Baldwin Robertson have received patent number 4,520,320 for their "synchronous phase marker and amplitude detector." This device has the ability to measure the phase and amplitude of a sine wave buried in noise. Though designed as part of an acoustic flowmeter patented last year, the detector can also be used, Potzick and Robertson claim, for phase and amplitude measurements in other research situations where the frequency of a signal is known but the signal-to-noise ratio is much less than 1. ■

NBS High-Tech Ceramics Program Geared to Needs of Industry

Modern technology has embarked on an age-old quest to turn base materials into "gold." But this time the pursuit is not alchemy; it is the manufacture of advanced ceramics.

And lead isn't one of the primary candidates for transformation, either, but other common constituents of the Earth's crust are. The starting materials of the manufacturing process are generally fine powders synthesized from such abundant elements as silicon and aluminum, combined with oxygen, nitrogen, or carbon. Before processing, these powders are usually pressed into a mold or otherwise compacted into the shape of the final product.

The mechanisms of the final transformation are still somewhat mysterious, but they generally require more heat than incantation. If all goes well, the result is an engineered material whose "gold" is its special properties.

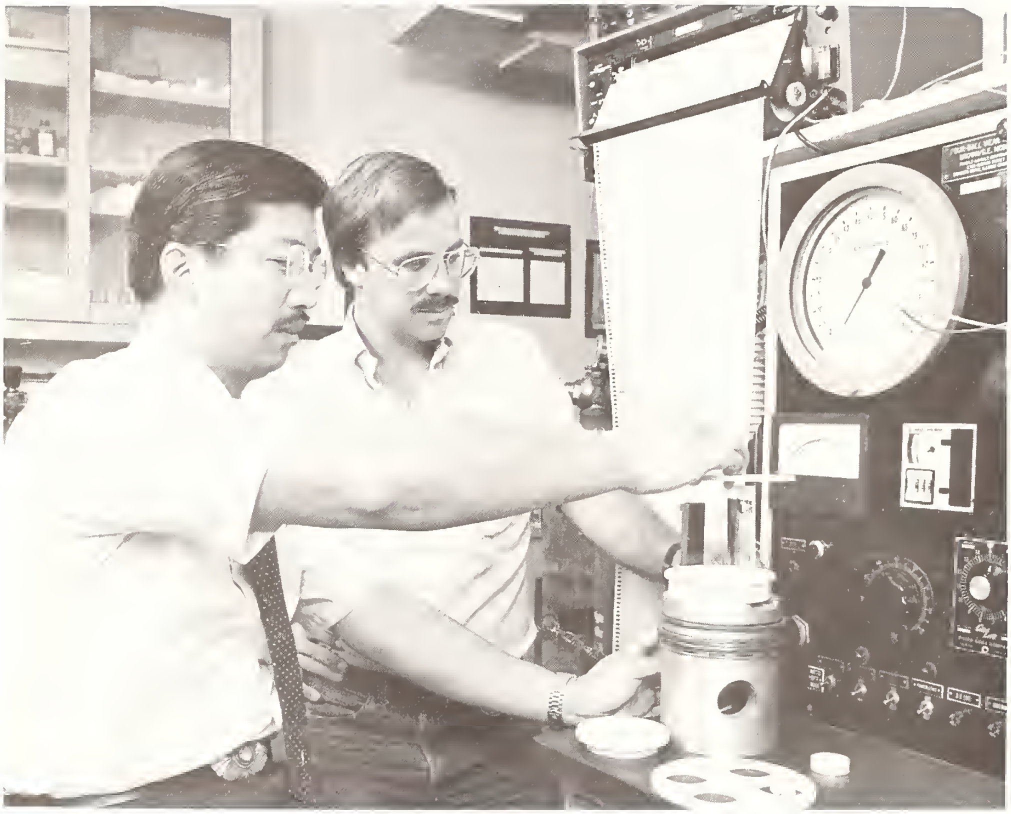
Such properties might include made-to-order electrical resistance or optical birefringence, among many other electrical/electronic and optical possibilities. Applications for electronic and optical ceramics range from substrate materials, the tiny slabs of raw material for holding semiconductor chips—the most mature and lucrative application for high-technology ceramics—to the future integrated optical circuit for switching and processing light signals without repeated conversion from electromagnetic energy to electricity and back.

The range of achievable mechanical properties is also broad. An adamantine hardness could combine with other desirable properties, like extreme heat, corrosion, and wear resistance, to make a structural ceramic capable of outperforming most other materials in a hot, chemically hostile, rugged environment.

In the NBS fracture laboratory, Dr. Brian Lawn follows crack growth on a computer monitor as a ceramic specimen is tested to failure.

Applications for structural ceramics are legion. Industrial cutting tools, for instance, could run at higher speeds and last from 5 to 50 times longer if they were coated properly with a ceramic such as silicon nitride. Advanced gas turbine and diesel engines could be transformed by ceramics such as silicon carbide, silicon nitride, and partially stabilized zirconia. Capable of running at temperatures hundreds of degrees higher than the top-performing metal alloy engines, they could deliver up to 50 percent more miles to the gallon than today's engines without the need for a water cooling system. Such engines could run on a broad class of fuels, and burn them clean enough that today's hydrocarbon emissions standards could become obsolete.

But note that the operative words in these scenarios are "if" and "would" and "could." Right now, electrical and electronics applications are the mainstay of today's $4.3 billion, free-world,



Dr. Stephen Hsu, foreground, and chemical engineer Richard Gates are shown in the NBS tribology laboratory with a 4-ball wear tester and several ceramic heat-engine components. The wear tester is one of several special or unique pieces of equipment researchers at NBS use to study friction, lubrication, and wear.

high-technology ceramics market. If that market is to grow to $25 billion or more by the year 2000, as some experts predict, many technical barriers must be overcome.

Technical Problems

"We have found that we can make defect-free ceramics to get enhanced properties, and we have learned to vary the composition to get special properties," says Dr. Lyle Schwartz, head of the Institute for Materials Science and Engineering at the National Bureau of Standards. "But we don't understand the basic materials and mechanisms well enough to achieve reliable, reproducible properties on a consistent basis."

Dr. Stephen Hsu, chief of the institute's Inorganic Materials Division, says this lack of understanding and control breeds "superstitious beliefs about what practices you have to follow to achieve reliable properties from the manufacturing process."

Knowledge and understanding have to replace conventional practice in the production process. Only then can high-technology ceramics realize their potential. And what are the prospects?

Schwartz, who is a materials scientist as well as director of the NBS materials institute, says, "the likelihood of technical success is very great, given sufficient effort to fill in the gaps in ceramic science and technology." And, he adds, it is imperative that we do so.

"The United States is in an international race to commercialize a new generation of ceramic materials," he says, "and a single example shows what's at stake.

"If the United States could commercialize ceramic engines and completely dominate the market over the next 20 years, the economy would reap remarkable benefits," Schwartz claims. "Compared to no involvement in this technology, it could mean a gain of $279 billion dollars in GNP, considering the full impact on the automotive industry, among others, and 250,000 additional jobs. By the same token, whatever fraction of the market we lose will, in proportion, erode those gains. It will also negatively affect our balance of trade."

The prize for winning the ceramics competition is well worth an extreme effort on everybody's part, he concludes. And he has redoubled the Bureau's efforts in ceramics to meet industry's needs for materials characterization, measurement and testing techniques, standards, engineering data, and cooperative technical support.

Opportunities for Cooperation

Special outreach activities complement the basic NBS high-technology ceramics program because, Schwartz says, "this industry needs more active support from us than just technical consultation. NBS has one of the more versatile capabilities for ceramics research in the world, with a number of unique or special facilities and an extraordinary breadth of expertise [see page 10]. We have to keep in touch with what is happening in industry and make sure our program suits their needs—and that they know about it."

At the present time, individual companies, other government

It Takes a Fine Touch to Make a Tough Ceramic

Careful preparation and processing transform the raw materials of common ceramics, the silicates, and other mineral compounds into high-performance materials variously known as high-technology, engineering, advanced, or fine ceramics. This transformation begins with the chemical synthesis of powder compounds from ceramic precursors. Ideally, the powder, often a mixture of two or more chemical compounds, is made up of very fine, maybe single-crystal, grains uniform in size. Unfortunately, small grains tend to clump, forming agglomerates, or larger non-uniform particles.

Usually a powder is doped with small amounts of chemicals that aid "sintering." Sintering refers to the bonding processes that occur during the firing of a "green ceramic," which is powder compacted into the shape of the final product. Heat causes the solid particles of the compact to coalesce, or densify, along their boundaries.

If the powder is free of traces of unwanted chemicals, if the particles are fine and uniform enough, evenly distributed, and tightly packed, and if sintering occurs to the maximum extent, the resulting material will be free of unwanted inclusions and pores and therefore totally dense and flawless. Barring surface defects caused by finishing, this product will exhibit desired special properties and possess the maximum strength possible, given the material's specific atomic structures and microstructure.

A defect-free structural ceramic can generally withstand compressive loads and hostile environments, including corrosive chemicals and extreme heat, better than any other material. The microstructure can be engineered, by doping, to give a ceramic some of the toughness characteristic of metals, but there are trade-offs. Temperature resistance might be lowered, for instance, or strength compromised.

Pores or unwanted inclusions trapped among the bonded particles, or surface cracks introduced by machining, also weaken the material. In fact, the strength of a ceramic is in inverse proportion to the size of its largest defect. And when a high-technology ceramic part is stressed beyond the limit of its strength, it performs like a crystal chandelier at a Wagnerian opera. It shatters.

agencies, and universities are working cooperatively with NBS to exploit NBS expertise and further their own aims. These cooperative interactions include two major ongoing data programs international in scope: one in x-ray powder diffraction and one in ceramic phase diagrams. Since direct person-to-person communication at the bench level is the most effective way to transfer technology, division chief Hsu and the entire staff of the NBS Inorganic Materials Division encourage and seek new opportunities for cooperation.

Researchers from outside NBS come to Bureau laboratories primarily through the Industrial Research Associate Program and the Guest Worker Program. Results of cooperative efforts are made public. Several unique NBS facilities may also be used on a limited proprietary basis by private organizations, for a fee.*

One recent major outreach effort, an NBS cosponsored conference on the future of the U.S. advanced ceramics industry, gave both perspective and direction to the national effort in high-technology ceramics. A summary of that conference is found on page 8.

* For more information on cooperative programs in ceramics or the use of ceramic facilities, call or write Dr. Stephen Hsu, A257 Materials Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2845.

Groundwork

The NBS advanced-ceramics program wasn't built in a day. Planning started in earnest in 1980 when Samuel Schneider, a ceramist with 30 years' experience at NBS, focused on the future prospects of a new generation of ceramic materials. "I wanted to explore the potential of ceramics for many different applications to meet national needs," Schneider says. "It was obvious that ceramics could be the answer to many advanced technological questions, especially where high temperatures or other special requirements make metals and polymers unsuitable. I would say the majority of high-technology products in the future will involve ceramics.

"Simultaneously [in the early 1980's], as it so often happens in science, a wave of interest in ceramics was growing worldwide, particularly in Japan. Japan was beginning to capture many of our high-tech markets at that time. Looking down the pike, I could clearly see there should be advanced-ceramics research at NBS. We have been in ceramics since 1910 and always at the forefront."

But what should the Bureau's role be in advanced ceramics? To answer that question, Schneider initiated three major studies: a broad technological/economic study and a study of the scientific aspects of advanced ceramics as related to technological needs, both carried out by experts outside NBS, and a study of the industrial advanced-ceramics environment, carried out by NBS technical staff "to give us a first-hand idea of where industry is, where it wants to go, and what it needs from us."

NBS researchers are... breaking new ground and upsetting old theories at the forefront of ceramic measurement science and technology.

The studies revealed that NBS' expertise is needed most in the areas of: 1) measuring and understanding how defects develop and evolve in the microstructures during powder synthesis, forming and compaction, firing, and machining; 2) understanding how the microstructure relates to the properties and performance of the finished material under conditions of simulated and actual use; and 3) understanding how the variables of the production process relate to the development of the microstructure.

Goal of the NBS Program: Reliability by Design

NBS' Hsu is a leading expert in tribology, the study of friction and wear. He points out: "Most people are confused about measuring friction and wear. People measure wear and report the accompanying frictional force. Yet wear is a cumulative process and friction is an instantaneous quantity. In ceramics, assumptions that we take for granted in metal systems are no longer valid. Entirely different procedures need to be developed for measuring ceramic friction and ceramic wear."

Dr. Brian Lawn, who is doing fracture experiments to determine what makes ceramics tough, comments: "All the old theories about how cracks in ceramics behave up to the point of failure need to be reassessed. When we actually look at cracks growing in in-situ experiments we see some-

Industry Must Be More Active for U.S. to Compete in Advanced-Ceramics Market

U.S. industry must take the lead and more aggressively exploit the potential of new advanced, or high-technology, ceramics. That was the consensus of 140 industry, government, and university leaders who attended a conference on the future of advanced ceramics held by the Commerce Department at the National Bureau of Standards July 10-11.

To withstand fierce foreign competition, "we have to get our act together," asserted Albert R.C. Westwood, Martin Marietta Corporation's corporate director of research and development. Among many recommended actions, Westwood urged industry managers to "overcome the commitment gap" by identifying and tackling pivotal technical challenges, targeting market niches that can be gained early, and developing bold and focused programs with accelerated schedules.

Rep. Don Ritter, R-Pa., told conference participants, "Nowhere is the competition in international trade more evident than in modern ceramic technology. There is still today in the United States only a weak U.S. industry in high-technology ceramics while the Japanese have made a strong commitment to become the major world source of these materials."

Like other speakers at the session, Ritter said U.S. industry "must accept responsibility for the bulk of the work needed to be a successful competitor in the world marketplace." The government can help, he said, but "massive government intervention cannot achieve competitiveness in any industry."

Estimates of the value of the ceramic market by the end of the century vary from $10 billion to $50 billion. The current market is about $4.3 billion. Japan's share of the market is about 45 percent and growing, while the U.S. share is near 35 percent and shrinking.

An economic study done by Charles River Associates, Inc., for NBS was reported on at the conference by CRA vice president thing very surprising. Cracks grow in quantum jumps. Even more surprising, we're finding that the critical events responsible for these jumps occur way behind the crack tip, contrary to what everybody has believed up to this time. We are currently reformulating the theory of ceramic toughness. Ultimately, we aim to be able to tell the processing people who make the ceramics exactly how they should tailor their materials for optimal toughness."

NBS researchers like Hsu and Lawn are breaking new ground and upsetting old theories at the forefront of ceramic measurement science and technology. While some researchers are studying ceramic precursors and examining powders produced by various techniques, including colloidal and solution chemistry and gas-plasma laser techniques, others are studying the agglomerates formed by spray-drying powders and the porosity in "green" (formed but unfired) ceramics. Still other researchers are applying various traditional and state-of-the-art processing technologies, including hot pressing and hot isostatic pressing for structural materials and co-evaporation techniques for electronic/optical thin films, and investigating the formation of grain boundaries and other sintering mechanisms. And, finally, they are investigating totally new materials and determining the chemical and physical properties and the performance of the final product.

Hsu has designed this broad-based but carefully focused NBS program to accomplish some very specific goals. "We want to determine the critical materials parameters that control the properties and the in-service performance of high-tech ceramic materials and develop measurement techniques and data to monitor these materials parameters," Hsu declares.

The other aims of the program, according to Hsu, are to develop the scientific understanding of how microstructures evolve through various processing stages, to determine the relationship between microstructure and mechanical and electrical properties, to identify the processing parameters that control the microstructure and other critical phenomena, and to provide theoretical models, phase diagrams, measurement methods, Standard Reference Materials, and materials property data so U.S. industry can optimize and control the effects of high-technology ceramic design and processing.

With the information from studies like these rather than superstition and incantation, industry may be able to turn base materials into products with golden properties.

by Julianne Chappell
NBS Writer-Editor

S.L. Blum. The study showed that though the United States is still ahead in basic research, Japan is quicker to capitalize on research and is ahead in process, or production, technology. Also, "Japanese firms already have earned large market shares in existing electronic ceramic applications and are well positioned to take advantage of spillover effects from these to other applications, particularly structural applications," Blum said.

Recent cooperative efforts in ceramics, including the formation of several research consortia at universities, also were applauded by Westwood of Martin Marietta. He warned, though, that "this response will not be enough to ensure that U.S. companies win their 'fair share' of emerging U.S. and world markets...." For this to happen, Westwood asserted, U.S. industrial management must develop a long-term commitment to exploit advanced ceramics in a variety of new and existing markets, spur materials scientists in their ceramics work, and do a better job of collecting and utilizing technical knowledge about ceramics generated in this country and abroad.

NBS director Ernest Ambler noted the recent improvement in U.S. industry/government/university cooperation in a range of research and development areas and stressed that the federal government had a key part to play in advanced ceramics by being the catalyst for industry interactions. Ambler cited NBS cooperative programs that bring industry researchers to work at NBS laboratories. He also told conference participants that the NBS advanced-ceramics program has been strengthened to make it more responsive to industry/university needs for data, measurement methods, and standards.

Conference participants agreed on the most critical areas for research and development and on the necessity for inter- and intra-industry cooperation to encourage growth, productivity, and competitiveness for U.S. advanced ceramics. The Department of Commerce was asked to help form an industrial steering committee to encourage that cooperation by investigating the feasibility of joint research and development efforts.

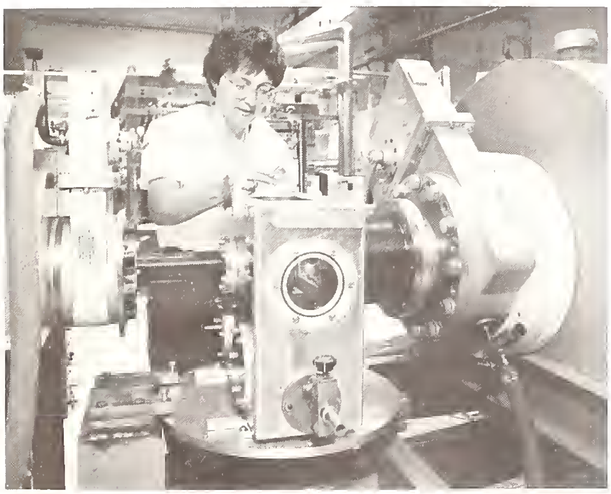
To obtain a complete summary of the conference, write or call Samuel Schneider, B309 Materials Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2891.

NBS Advanced-Ceramics Expertise, Facilities Available to Industry

To be successful, the advanced ceramics industry needs measurement-related science and technology such as measurement methods for ceramic structures and properties, generic materials-property data, and well-characterized reference materials from the National Bureau of Standards. This was the main point made last spring by Dr. William R. Prindle of Corning Glass Works when he testified before a subcommittee of the U.S. House of Representatives' Committee on Science and Technology.

Prindle, Corning's director of administrative and technical services, was testifying to the Bureau's wisdom in attempting to augment its existing, in his words, "world-class activities and facilities" dedicated to advanced-ceramics research.

Prindle and other industry leaders support NBS because it has "a proven track record in providing successful technology transfer that is needed by industry," Prindle told Congress.



Dr. Kay Hardman-Rhyne is about to subject a ceramic specimen to small-angle neutron scattering experiments at the 20-megawatt NBS research reactor.

Dr. Stephen Hsu, chief of the NBS Inorganic Materials Division, knows the ingredients of this success: the right facilities, the right programs, the right people, and a willingness to go more than half way to get the others involved. "The door to every laboratory is open," Hsu says, "and we have experts in every ceramics area and across all disciplines. Wherever cooperation of mutual benefit is possible, we pursue it. It is the best way we know to make a two-way exchange of knowledge and technology."

Hsu invites industry managers and researchers involved in advanced ceramics to visit the NBS laboratories in Gaithersburg, Md., and to meet the staff of the Inorganic Materials Division. Visits can be arranged by calling Hsu on 301/921-2845. In the meantime, here is a brief overview of the research expertise and facilities.

A Wide Range of Research

Dr. Edwin Fuller, who heads the NBS efforts in sintering science, says the Bureau addresses all generic, measurement-related areas of advanced-ceramics science and technology. Precursors are studied; powders are synthesized, characterized, and compacted; green ceramics are characterized and processed; evolution of the microstructure during production is monitored; and sintering mechanisms are investigated.

Finally, the physical and mechanical properties of finished materials are determined, and materials are performance tested under conditions of simulated use. Such tests give researchers the opportunity to test theories of how ceramics fail, or conversely to find out what makes them succeed. Results in all areas are used to revise old or develop new theories and, most important, to link performance to basic properties, properties to structure, and structure to the manufacturing process.

Properties/performance testing also satisfies some of industry's immediate needs, Fuller says, and thus constitutes a bridge between industrial applications and NBS' basic studies. "Most of the finished structural and optical/electronic ceramics performance tested at NBS come from manufacturers, and the test results serve their near-term purposes in product development as much as they do our long-term goals," he points out.

Most companies are pleased with the expertise they find at the Bureau and with the divergent focuses of their near-term and NBS' long-term research. "One senior engineer from an engine company told me they found our testing so useful they decided to copy our mechanical properties and performance lab," Fuller says. "They've even duplicated some of the special purpose measurement equipment we've developed here."

Optical/Electronic Ceramics

The general theme of basic science and technology for future applications holds true in the optical/electronic area, according to Dr. Albert Feldman. Feldman, a physicist, directs the NBS optical-ceramics program.

He has in fact been contributing to the future of optical-ceramics technology since he joined NBS in the 1960's. And he gives one example of how NBS draws on expertise developed in the past to advance measurement science for the future: "Bismuth silicon oxide is one of the important optical ceramics today, but we first looked at it in the late 1960's, soon after it was developed at Bell labs." BSO, as the material is called, rotates the polarization of a beam of light passing through it. In other words, it makes light particles rotate in one direction only. "We at NBS developed and characterized a new BSO material with the opposite sense of polarization rotation," Feldman adds.

Today BSO is a candidate for optical memories that may be found in an optical computer of the future. And NBS is again studying this material. "Exposure to light changes a basic optical property of BSO, and this behavior is desirable," Feldman explains. "But nobody yet understands what mediates the behavior. We think it is caused by impurities, but we don't yet know what those impurities are."

Of course, BSO is but one of many optical materials NBS is studying. Materials for multifunction devices, also known as integrated optics, are high on the priority lists of manufacturers, who provide sample materials for study. But the Bureau is looking farther into the future than a hybrid optical circuit made up of both non-ceramic electronic materials and ceramic optical materials. "That will be the next generation," Feldman says. "After that will probably come a generation of monolithic [or single-material] optical circuits made up of non-ceramics. But then, we may have a generation beyond that of monolithic ceramic devices that will use ceramics for both optical and electronic functions."

Feldman is optimistic because he and other NBS researchers are using a relatively new processing technique, called co-evaporation, to develop totally new thin films, materials that do not exist in nature and have never before been produced. These thin-film materials have current application in advanced optical coatings. Other processing techniques for optical materials in use at NBS include electron-beam and ion-assisted electron-beam deposition and sputtering.

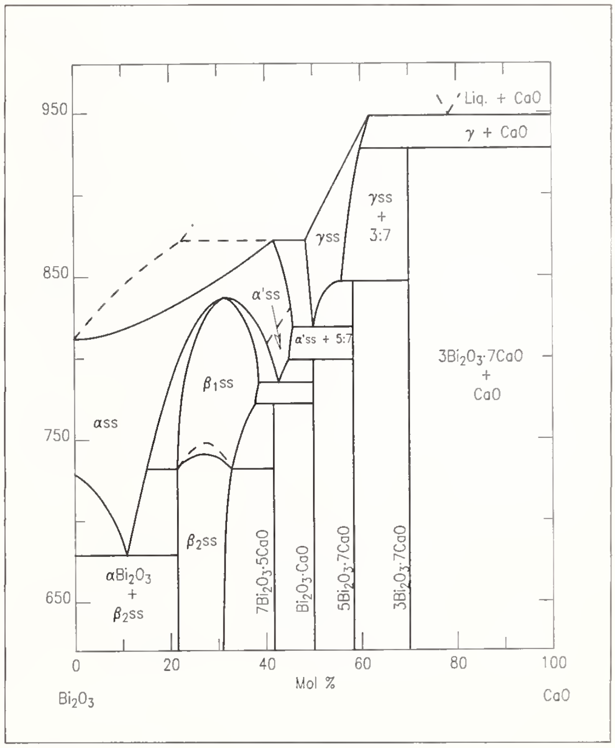
Techniques used for characterizing chemical composition and structure include: x-ray diffraction and electron microscopy for materials structure; electron spectroscopy for chemical analysis; Auger spectroscopy, secondary ion mass spectroscopy, and Rutherford backscattering for depth profiling; and Raman spectroscopy for ionic bonding. For optical characterization, NBS researchers employ channel spectra analysis, m-line spectroscopy, optical scatter, and optical absorption among other techniques.

Powder Synthesis, Processing, and Characterization

In the area of structural ceramics, Dr. Kay Hardman-Rhyne and Dr. Alan Dragoo, both chemists, head the groups most directly involved in powder synthesis and compaction and in the characterization of powders and green ceramics.

Hardman-Rhyne uses several powder-synthesis techniques, including the sol-gel method, precipitation, other chemical means, and gas-plasma methods. She uses the Bureau's 20-megawatt research nuclear reactor for small-angle neutron scattering and wide-angle neutron diffraction studies of green ceramics and finished materials to determine crystal structure and characterize microdefects.

Dragoo's group is concerned with characterization, including crystal structure and physical properties, of powders after synthesis and prior to compaction. Of particular interest are powder particles, or agglomerates, produced by the spray drying of powders.



This bismuth oxide/calcium oxide phase diagram comes from a computerized database being developed by NBS and the American Ceramic Society under their jointly funded multimillion-dollar Phase Diagrams for Ceramists Program.

"We want to know what signatures identify a powder as one that will densify," Dragoo says. "Manufacturers will be able to specify what they want in a powder once we determine what measurements are critical."

Fuller studies the transport mechanisms and the kinetics of sintering and the physical properties of sintered materials. He is interested in techniques that give information on structure and grain boundaries.

Dr. John Hastie leads a group concerned with high-temperature chemistry. Hastie's group includes the ceramics phase diagram data center at NBS. The

Research chemist Carl Robbins is using a computerized image analysis system to quantitatively analyze an enlarged photograph of ceramic powders.

program, a joint NBS/American Ceramic Society effort, is undergoing a major expansion: The American Ceramic Society is working to raise $4 million to support its share of the effort. "There are about 20,000 phase diagrams out there in the literature that need to be collected, evaluated, and published," he says. "That's what we're doing with the help of experts all over the world. And we're also developing a computerized database that will one day be accessible through the American Ceramic Society to subscribers everywhere."

Phase diagrams are graphic representations of information about the physical and chemical states of materials and the thermodynamic transitions between phases, with emphasis on the crystalline phases. Ceramists and engineers use them to choose and design materials for particular applications. The NBS/American Ceramic Society ceramics phase diagram program will put about $1 billion worth of research to better use, Hastie claims.

NBS facilities for materials characterization include x-ray diffraction equipment; scanning and scanning-transmission electron microscopes; capacitance/impedance equipment for measuring complex a.c. properties; particle-sizing equipment such as an x-ray sedigraph for measuring the rate of settling of particles out of a liquid and a photon correlation spectrometer for measuring particle size by light scattering due to the Brownian motion of particles; a 3-point BET apparatus for surface-area measurement; and a mercury porosimeter for measuring pores connected to the outsides of particles. NBS researchers are working on a technique called x-ray line broadening to measure grain size, and they are augmenting an image-analysis technique for determining the size and shape of powder particles and the properties and structure of a finished material.

Sintering is accomplished at NBS by a variety of methods, ranging from hot pressing to hot isostatic pressing. A number of conventional tube-type furnaces have been modified for special atmospheric environments. A tungsten-mesh furnace can go to 2500 °C. One induction high-temperature furnace operates in a special enclosure, uses a high-frequency field, and works something like a transformer to achieve temperatures up to 2600 °C.

Mechanical Properties and Performance

In mechanical properties and performance, NBS researchers study the processes affecting the structural reliability and performance of ceramics over a range of temperatures and in aggressive environments. Theoretical and experimental work is aimed at understanding fracture and deformation mechanisms and their relationships to microstructure.

Dr. Sheldon Wiederhorn, a chemical engineer, leads the group primarily responsible for determining mechanical properties at low and high temperatures, looking at materials performance under a variety of conditions, and determining failure mechanisms and materials durability.

Hsu's group focuses on tribology—friction and wear studies. Dr. Stephen Freiman heads the group concerned with the mechanical properties and performance of composites. Also, Freiman's group has developed a thermal-wave nondestructive technique for monitoring the microstructure of a ceramic during and after sintering. With modifications, the technique may one day prove useful as part of a production line system for monitoring and controlling the manufacturing process.

Special facilities in these areas include mechanical test equipment such as general purpose universal test machines; a high-temperature controlled-environment facility for testing in a fossil-fuel combustion environment; a high-temperature creep laboratory; a high-temperature, high-pressure facility with temperatures as high as 1000 °C and pressures as high as 1000 psi; a green-ceramics laboratory with a high-temperature vacuum facility; hydrothermal test equipment; a unique dynamic hardness tester; and a newly developed and unique tribometer for testing friction and wear at temperatures up to 1500 °C. The x-ray facilities for microstructural analysis are being increased and enhanced to permit better characterization, including measurement of residual stress. J.C.

Fiber Optics: Lighting the Way to a Communications Revolution

Optical fibers. These hair-thin strands of glass or plastic that conduct light have long been used for tasks as simple as looking pretty—like the miniature light "trees" with branches that sparkle at their tips. Now they are being used to light the way to a revolution in the way we communicate. That is why researchers at NBS are devoting their energies to help U.S. industry speed the use of optical fibers.

Practically everyone in the telecommunications business agrees that optical fibers are the wave of the future in moving information from place to place. As NBS physicist Doug Franzen puts it, "The prevailing mood seems to be very upbeat, with some people suggesting that optical fibers will eventually replace nearly all the long distance copper communications cable."

Optical fibers are rapidly being introduced into all kinds of telecommunications applications, from networks within single buildings to intercity telephone links. They are used to send data from one computer to another and to send operating signals from a plane's cockpit to control the engines, flaps, and other systems of the aircraft.

There are two main reasons for the sudden growth of applications using fiber optics: their huge capacity for rapidly moving large amounts of information and their immunity from electrical interference from outside sources. "Since the information is carried by light waves inside an insulator, such things as lightning, sparks, motors, and other common sources of electrical interference have no effect," Franzen says, adding that optical fibers "make ideal communication links in electrically noisy environments."

Optical fibers also provide high-security communications because the information in the cable can't be tapped without physically attacking the cable, "and that always leaves a telltale trace," Franzen says.

A rapidly expanding technology such as fiber optics always has growing pains of one sort or another, and this is where NBS comes in. As a non-regulatory research agency, NBS' work promotes compatibility among components, especially through uniformity of measurements. Most basically, when new concepts and novel terminology are being invented so fast, it is hard for everyone to keep up with and agree on definitions. And when the state of the art is advancing rapidly, it is difficult for users, researchers, and manufacturers to reach a consensus about the best way to measure a given parameter, even if the parameter is well defined.

All this brings a certain amount of chaos to the marketplace. Buyers and sellers don't understand and follow each other's specifications, leading to disputes over whether contracts have been satisfied. What's more, when measurements on the optical fiber systems are made independently using different methods, the results seldom match, leading to further disputes.

This was the situation facing the fiber optics industry until the major manufacturers, some important users, and NBS got together to work out these problems.

One of the first accomplishments was the compilation of

Here electrical engineer Robert Gallawa measures the bandwidth of multimode optical fibers. The measurements are done using three different techniques: frequency domain, time domain, and pulse spectrum analysis.

a glossary of terms used in fiber optics communications, which already has been adopted and published by the Institute of Electrical and Electronics Engineers. Drawing on the expert opinions of a large panel of industry and NBS representatives, the glossary defines more than 400 terms commonly used in the industry. It promotes clearer language and less confusion in contracts, specifications, and technical papers written about fiber optics. "This may seem like a rather elementary job," says Franzen, "but we found that the language differences among optical fiber pro-

How Optical Fibers Work

Telecommunications-grade optical fibers are usually made of very pure glass, because impurities tend to absorb and scatter the light. This scattering weakens the intensity and reduces the distance the light can travel through the fiber without extra amplification. Other conditions which dim, or attenuate, the light include variations in the diameter and micro-bends in the fiber.

There are two basic kinds of fibers: those with a constant index of refraction from the center out to the surface and those with an index that gradually decreases from the center out. Both kinds usually have a separate low-index covering that enhances the transmission properties. Then the fiber is surrounded by a plastic buffer coating for protection.

As light rays pass through the constant-index fiber, most of them strike the walls at grazing angles and are totally reflected, so little light escapes through the wall of the fiber. However, if the surface of the fiber or covering is uneven or scratched, or if the fiber is bent in a small radius, losses can increase.

In graded-index fibers, light is guided in a similar fashion except that the gradually changing index of refraction bends the light instead of reflecting it. Most of the light is confined to the central axial region of the fiber, because if a ray leaves this region, it is bent back toward the center. The main advantage of graded-index fiber is higher frequency operation.

The higher frequencies are allowed because almost all of the light travels the same path length through the fiber (single-mode operation) and the pulses of light that carry the information can be closer together without getting mixed up. In constant-index fibers, the rays can bounce around in many ways, taking many different paths, some longer than others. By the time they reach the other end, two pulses that started out separately might arrive at the same time and get mixed together, destroying the information each carries. This is a result of multimode operation, and it limits the frequency of pulses to a certain value.

The pulses of light are generated by light-emitting diodes or lasers controlled by electronic circuits. The light can be focused on one end of the fiber by a tiny lens, and a similar lens assembly can be attached to the opposite end to focus the output beam on a photodetector. The photodetector turns the light pulses into electronic impulses which are interpreted by more computer circuits.

If the distance to be covered is too great for a single length of fiber (the present limit is 30 miles or so), several fibers can be alternated with amplifiers. The amplifier, or "repeater", detects the weak output of one fiber, converts it to an electronic signal that drives a diode or laser, and retransmits the new strong light pulses to the end of the next length of fiber. This process can be repeated as many times as necessary to cover the distance desired.

The information is received at the far end of the fiber by a photodetector, usually another kind of diode, that converts the light pulses into electrical signals that can be processed by computer circuits or sent on wires to their ultimate destination.

Each of these transitions from device to fiber to device, as well as the losses in the fibers themselves, saps a little of the light's strength, but these losses can be minimized with careful attention to the characteristics of all of the components. This requires precise measurement of the optical and electrical properties of each item in the light path, so that the design of the entire system can be optimized.

ducers and users were an important barrier affecting the industry."

NBS and the industry, working through the Electronic Industries Association, have started to develop voluntary standards for the methods of measuring the properties of optical fibers so that when different laboratories measure a given fiber they obtain comparable results.

In order to carry useful amounts of information over long distances, the fibers must be made very precisely. Their diameters must be held constant to a few ten-millionths of an inch. Their purity must be extremely high, and their optical properties must be controlled so that they vary in a precise manner over the cross section of the fiber.

Once manufactured, the fibers must be tested, or measured, to see that they meet advertised specifications. For instance, light gets dimmer, or is attenuated, as it travels down the fiber; the amount of attenuation is one of the most important parameters measured. Another is the bandwidth, which is a measure of how much information can be transmitted over the fiber in a given length of time. These and other measurements must be made on samples at the factory before customer orders can be filled.

NBS has developed standard measurement techniques or calibration services for bandwidth, core diameter, index of refraction profile, and attenuation.

Special connectors are used to attach the fibers to each other and to light-sending and -receiving devices. Designing the connectors requires knowledge of certain other fiber parameters, such as the acceptance angle, which describes the size of the tiny cone of light leaving the end of the fiber. Light outside that cone will not travel successfully along the fiber, and will be wasted. So measurements must be made on the fibers and the devices connected to them to obtain optimum results.

The difficulty with all this measuring activity is that the measured values too often turn out to depend on the method of measurement used. For example, one company measures its fiber and certifies the amount of attenuation. Using his own techniques, a customer may measure more attenuation. This means the customer may reject the fiber or he may be led to design his system to use more power than is needed to transmit over a given distance, or use more "repeaters" or light amplifiers along the way. In any case, his costs are increased.

One company estimated that its costs of reaching an agreement on measurements with a certain large customer included some 400 staff hours of lab time, at least twice that much administrative time, and roughly 50,000 miles of travel. What's more, the customer probably spent a third to half as much time and money as well.

The solution is to use standardized measurement methods. NBS has developed standard measurement techniques or calibration services for bandwidth, core diameter, index of refraction profile, and attenuation. The Electronic Industries Association and other standards groups have voluntarily accepted these standards for industry and other standards are being developed as the need becomes apparent.

As a non-regulatory research agency, NBS' work promotes compatibility among components, especially through uniformity of measurements.

Standardization brings other economic benefits because it allows firms to concentrate their technical activities on innovation, especially cost-reducing innovations. This improves their competitive position in world as well as domestic markets, an important consideration in the fiber-optics market where foreign competition is tough.

In this process of reaching an industry-wide consensus on measurement standards and methodology, the crucial word is "voluntary"; NBS has no regulatory powers. "What NBS can do," says Franzen, "is try to make a compelling scientific case for making a measurement in a certain way, so that the industry will agree that everyone's interests are best served by accepting the procedure as a voluntary industry standard.

"So far," he adds, "we have been fairly successful, but there are still substantial measurement challenges facing NBS and the industry. We need to work on standards and measurement techniques for evaluating such things as light sources, detectors, multiplexers, and the whole gamut of integrated optical circuits just now beginning to be developed."

by Collier Smith
NBS Public Affairs Specialist

New Technique for Measuring Antenna Performance Pays Off

The patience and persistence of National Bureau of Standards scientists and engineers have resulted in some big savings for U.S. industry.

The NBS researchers developed a revolutionary new way of measuring the performance of advanced microwave antennas that has, for example, saved RCA over $6 million in building and testing costs for the Aegis radar antennas which were installed on 16 U.S. Navy cruisers.

The origins of the NBS development go back 25 years to a project designed to provide an improved measurement of the speed of light. Theoretical calculations for that project, the researchers found, could also be applied to the measurement of performance characteristics of microwave antennas. Until recently, virtually all antenna measurements were made on large, outdoor (far-field) facilities. Measurement accuracies were typically no better than plus or minus 10 to 20 percent because of the reflections, interference, and distortions; the older techniques were not suitable for measuring large, sophisticated satellite antennas or a new class of antennas called phased arrays. Rising land costs also made new outdoor facilities prohibitively expensive.

Douglas T. Tamura, an electronics technician, aligns antennas being calibrated on the extrapolation range which is part of the near-field facility.

Beginning in 1973, NBS constructed a large indoor antenna measurement facility that allowed engineers to measure the phase and amplitude distribution of the fields directly in front of an antenna and, through the use of their previously developed mathematical formulas, calculate the far-field radiating characteristics of the antenna. This method, called the planar near-field scanning technique, was found to be quite useful for satellite antennas and for the phased-array configuration, a grouping of many small antennas whose phases and amplitudes are electronically controlled to produce various beam configurations and to point the beam in different directions. The new technique had the potential for speeding up the measurement process, improving accuracy, providing more complete information, and reducing both the staff needed and the cost.

The next big hurdle was getting the near-field technique accepted by industry and other government agencies. "Companies had economic investments in far-field ranges, they were not going to be amenable to a new scheme when they had such a large investment," says Charles K.S. Miller, chief of the NBS Electromagnetic Fields Division.

"We were very concerned about transferring the technology and took advantage of opportunities as they came up," adds Dr. Ramon C. Baird, leader of the NBS antenna systems metrology group which developed the technique. Whenever members of his group visited other government agencies and private companies they took the opportunity to explain the advantages of the near-field technique.

Over the years, Baird's group has presented 30 papers at national and international conferences, offered three courses on near-field scanning at NBS in Boulder, and put on courses at NASA's Lewis Research Center, Hughes Aircraft Company, Intelsat, and TRW Corporation. Staff members also lectured at California State University and the Technical University of Denmark.

...saved RCA over $6 million in building and testing costs for the Aegis radar antennas which were installed on 16 U.S. Navy cruisers.

The proselytizing began to pay off. Gradually large aerospace and defense firms, such as RCA and Hughes, constructed near-field antenna ranges and realized the advantages of this technique. Hughes found that the near-field technique reduced the time needed to measure complex, phased-array antennas for the U.S. Army from 1 month to 12 hours. Dollar savings, often amounting to 1 percent of the value of the antennas, were as much as $22,000 each.

"We've been using our near-field facility for about 1½ years," says Dr. Robert D. Ward, a senior project engineer in Hughes' Space Communications Group at El Segundo, Calif. "We started getting good results immediately and we've been very pleased."

Ward notes that his group is located in a congested area near

Measuring in the Near Field

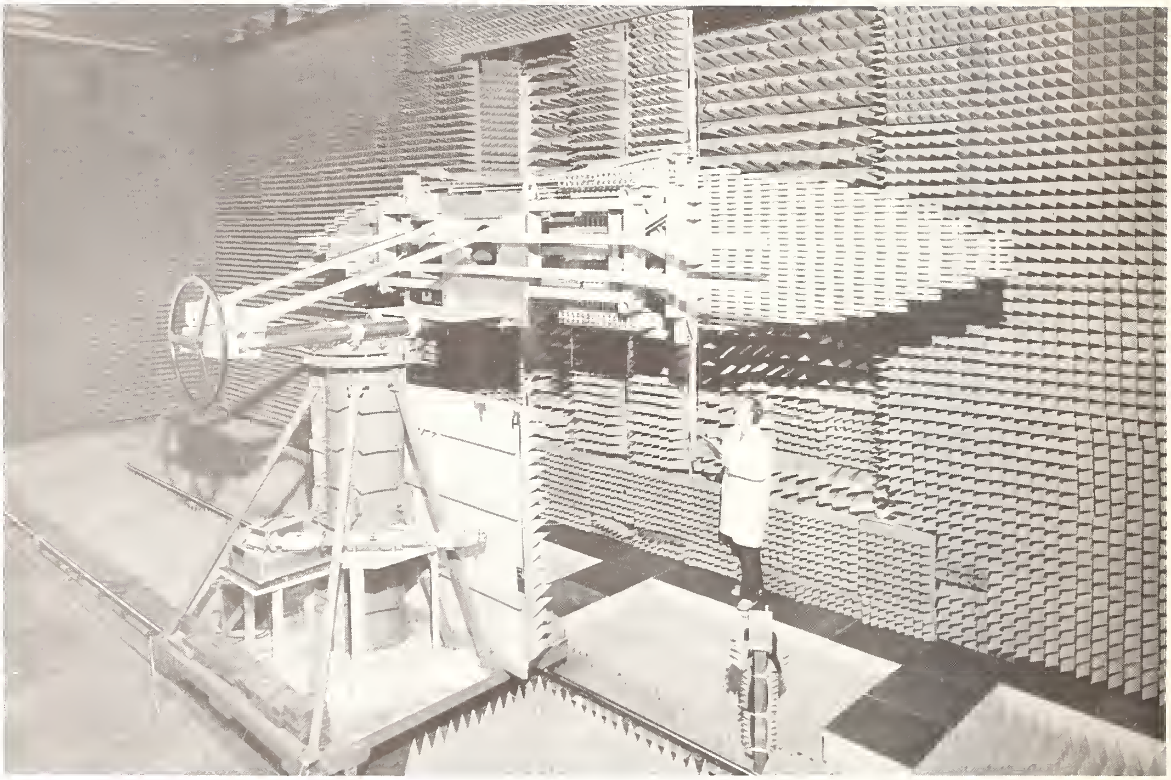
The making of near-field antenna measurements is a three-fold process involving a facility, a mathematical formulation, and a computer program. At the NBS Boulder laboratories, measurements are made in a 30-foot-high bay which is lined from floor to ceiling with dark blue, carbon-impregnated microwave absorbing material. These absorbers are designed to ensure the integrity of the measurements by sopping up any stray microwave radiation and minimizing reflections and distortions. The antenna to be measured is mounted on a stand in front of a wall of absorbing material. The antenna remains stationary while measurements are being made. A small antenna probe, in front of the absorber wall and pointed at the antenna being measured, moves in a plane taking thousands of measurements at regularly spaced points near the antenna.

The next step—the mathematical manipulation of this near-field data into far-field patterns—was made possible by the work of Dr. David M. Kerns, an NBS scientist now retired. In the 1960's, Kerns developed rigorous mathematical equations that could be used to calculate the far-field characteristics of an antenna from measurements made in the near field. The basic mathematical operation is a Fourier transformation which allows a complicated radiation pattern to be expressed as the sum of a number of simple plane waves. A series of computer programs, developed by NBS' Allen C. Newell and his colleagues, perform these computations quickly and permit a variety of measurement parameters to be obtained on a number of different antenna configurations and frequencies.

The far-field pattern, gain, and polarization are three of the main antenna properties, or parameters, measured by this technique. The far-field pattern is the angular distribution of the antenna's energy output at a great distance from the antenna (in the far field). The far-field pattern of energy distribution does not change no matter how far out the measurement is made. Gain is a measure of how the energy is focused or concentrated in a given direction; it is analogous to the focusing of light into a beam in an automobile headlight. In a radar system, for instance, the higher the gain of the radar antenna, the farther away an object can be detected. Polarization describes the direction of the antenna's electrical field.

The near-field measurement technique has a number of unique advantages: It can be used at the end of an antenna production line to evaluate performance, align elements, and diagnose problems; it is especially useful for measuring phased-array antennas; and it is the method of choice for measuring many satellite antennas. In the case of newly built antennas, the near-field method can identify deformities in the shape of reflectors which, if not corrected, could cause poor antenna performance. Similarly for phased-array antennas (composed of hundreds of small antennas electronically controlled to function as a single large one), the near-field technique can easily and quickly spot one of the small antennas that is out of adjustment. Satellite antennas are often lightweight, unfurlable structures which operate effectively in the very low or zero gravity environment of space but which pose problems for ground-based testing as the lightweight structures deform easily. Near-field testing virtually eliminates this problem because, once mounted, satellite antennas do not have to be moved for measurement purposes.

NBS has tripled the size of its near-field facility to accommodate large antennas such as the 25-foot-long, 4-foot-high AWACS instrument. Measurements are still taken in a plane, but researchers are also working to perfect cylindrical and spherical scanning techniques. These new techniques will permit 3-dimensional measurements and measurement of sidelobes and backlobes—undesired radiation which leaks out the sides or rear of the antenna. NBS' Dr. Paul F. Wacker, now retired, developed a method for simplifying the calculations for the spherical technique and NBS electronics engineer Richard L. Lewis developed computer programs based on Wacker's method. The Technical University of Denmark is now doing practical tests using the spherical technique. The cylindrical technique was first developed and implemented at the Georgia Institute of Technology. NBS has also developed computer programs for cylindrical scanning which are now being used in several laboratories throughout the world. NBS has the capability for using all three (planar, cylindrical, and spherical) measurement techniques.



Engineering aide David Dean takes readings of phase shifter settings of the large (4 feet by 25 feet) AWACS antenna being measured in the newly enlarged near-field facility.

Los Angeles International Airport. "We can't build an outdoor range easily. The fact that near-field measurements can be done in a room similar to an anechoic chamber is a big advantage to us," he adds.

The technology transfer efforts by NBS have made the near-field methods the dominant force in the evaluation and testing of large, complex antennas. Eighteen U.S. companies and government agencies have now constructed about 30 major near-field facilities. An additional 11 near-field facilities have been built by NATO and other allied countries. In almost all cases, NBS has been involved in either the design of these facilities or in supplying the computer programs. Even after the facilities have been constructed, NBS continues to calibrate probes used by these organizations as part of the near-field technique.

Dr. Alan E. Holley, a technical staff manager at the Hughes' Ground Systems Group in Fullerton, Calif., says he uses the near-field technique as a diagnostic tool to check for flaws in complex phased-array antennas being built for the U.S. Army. "We find things [flaws] that would never have been found on a far-field range," he explains.

Calling NBS in the "forefront" of near-field technology, Dr. S.J. Hamada, manager of TRW's Antenna Systems Laboratory in Redondo Beach, Calif., says his group is using the near-field technique for acceptance testing on all projects. "Nowadays, you can't do far-field tests," he adds, noting that state-of-the-art, high-frequency antennas would require a 7-mile-long outdoor test range. He terms near-field testing "the measurement of choice in the future."

NBS' involvement with the near-field technique will continue for some time. Its main near-field facility at the Boulder laboratories was recently expanded so that large antennas can now be measured and calibrated. This facility is available for use on a reimbursable basis by industry, government, and academia. Arrangements should be made with Allen C. Newell, Division 723.05, National Bureau of Standards, Boulder, CO 80303.

by Fred McGehan
NBS Public Affairs Specialist

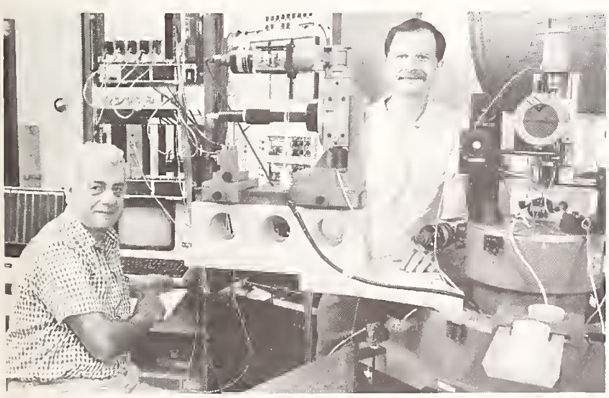
Seven NBS Inventions Picked as Significant Technological Advances

Inventions in computer science, microelectronics, and automated manufacturing were among seven entries of the National Bureau of Standards given I-R 100 awards this year. Those seven awards represent the highest number given to any single participant in this year's competition.

I-R 100 awards are given annually by *Research & Development* magazine to honor the "100 most significant" new technical products of the preceding year. Presentations were made September 26 in Chicago and bring to 44 the number of I-R 100 awards NBS has received since it first started taking part in the competition in 1973.

Descriptions of the award-winning technological advances follow.

Pictured here from the left are Richard J. Linn, Jr., Jeffrey Gura, Daniel Rorrer, and Wayne McCoy with (seated) J. Stephen Nightingale who were presented with an I-R 100 award for developing a transport protocol test system. Not pictured are co-winners Thomas P. Blumer and John C. Burruss.



George A. Candela (left) and Deane Chandler-Horowitz pose with their computer-controlled principal-angle ellipsometer.

Transport Protocol Test System

In July 1984, 14 computer manufacturers and communications companies demonstrated for the first time how computers from different manufacturers could communicate using international networking standards. The award-winning transport protocol test system developed by an NBS-led team helped make that demonstration possible. The system, the first of its kind, is a set of complex software programs that allows vendors and users to self-test their computer systems to make sure they conform to the networking standards. Included in the test system are a reference implementation, tests, a test interpreter, and an exception or error generator. Until now, implementations of the network standards were verified by using them and then correcting errors as they were discovered. The test system has been made available to private industries and has been used successfully by major vendors and users.

The winners of this I-R 100 award are Richard J. Linn, Jr., Wayne McCoy, J. Stephen Nightingale, Daniel Rorrer, and Jeffrey Gura, all from the NBS Institute for Computer Sciences and Technology, and Thomas P. Blumer and John C. Burruss from Bolt, Beranek and Newman, Inc.

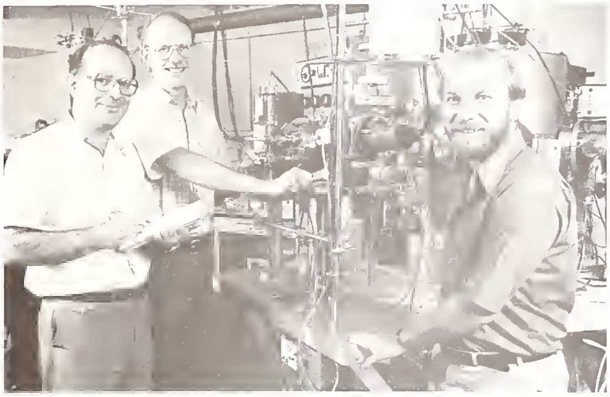
Computer-Controlled Principal-Angle Ellipsometer

Dr. George A. Candela and Deane Chandler-Horowitz of the NBS Center for Electronics and Electrical Engineering were honored for developing a fully automated, high-accuracy ellipsometer for measuring the optical properties of thin films on various materials. The device—which is modular and built mainly from commercially available components—can determine the thickness and refraction index of thin films more accurately and with greater ease than previously possible. This is important to industries such as semiconductor manufacturers which need accurate ellipsometers to produce quality products.

The device...can determine the thickness and refraction index of thin films more accurately and with greater ease than previously possible.

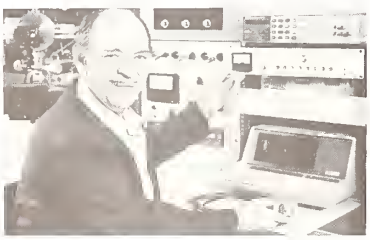
Candela and Horowitz' device, unlike commercially sold ellipsometers, operates automatically at the principal angle. Because of the instrument's accuracy, it can be used to make reliable measurements on thin-film growth, monolayer surface contamination, surface damage, or surface crystallography.

The value of thin-film-measuring instruments is well-known in industry, and many sectors of the economy depend on accurate measurements. The integrated circuit industry, for example, needs such instruments to evaluate and control oxidation or the deposition of metallic and dielectric films. The NBS instrument makes reliable measurements of commercially important films in integrated circuits that are not accessible to existing equipment.



Standing with their improved monochromatic electron gun used in this surface science instrument are (from the left) Robert J. Celotta, Daniel T. Pierce, and Charles S. Feigerle; co-winner Alfred Seiler was not present.

Posing with their automated, high-precision capacitance bridge are Robert D. Cutkosky (left) and Lai H. Lee.



Ronald W. Shideler is shown with his parametric amplifier electrometer.

High-Current Monochromatic Electron Gun

A team of NBS researchers earned an I-R 100 award for the development of a new type of monochromatic electron gun—a device to produce a beam of electrons—that is expected to have wide application in surface science, electron spectroscopy, and electron lithography.

Most electron guns make use of a separate monochromator stage to narrow the energy spread of the electrons, but there is a strict limit on the maximum beam current that a monochromator can provide at any given resolution. The new gun circumvents these limits by making use of a "negative electron affinity" (NEA) photocathode similar to those used in night-vision devices to produce a high-current electron beam with a very narrow distribution of electron energies. The device has produced currents in excess of 1 microamp with an energy spread (FWHM) of 31 meV—five times better than the closest competitive product.

The high-current monochromatic electron gun was developed by Drs. Daniel T. Pierce, Robert J. Celotta, Charles S. Feigerle, and Alfred Seiler of the NBS Center for Radiation Research.

Parametric Amplifier Electrometer

Ronald W. Shideler, an electronics engineer in the NBS Center for Analytical Chemistry, received his award for inventing a device designed to measure extremely low levels of current through the computer-controlled data collection systems of mass spectrometers.

The new electrometer is an improvement over existing models because of its ability to measure signals at levels close to the theoretical limit of noise. It features switch-selectable response times so the operator can control the tradeoff between response time and noise level, two important factors in performing a highly precise and accurate mass spectrometric chemical analysis at low levels (parts per million or lower). Though Shideler's invention was designed for use with NBS-designed thermal ionization mass spectrometers, it may be used with all similar types of instruments and measurement systems.

Type 3 Capacitance Bridge

Robert D. Cutkosky and Lai H. Lee of the NBS Center for Basic Standards earned an I-R 100 award for the design of an automated, high-precision capacitance bridge.

Capacitance bridges are used in laboratories around the world for calibrating standards of electrical capacitance. Their device, now called the NBS type 3 capacitance bridge, is the first fully automatic capacitance bridge capable of the precision and accuracy required by standards laboratories. It operates at a basic accuracy 1,000 times better than that of its closest competitor.

Their device, now called the NBS type 3 capacitance bridge, is the first fully automatic capacitance bridge capable of the precision and accuracy required by standards laboratories.

The type 3 capacitance bridge can select from and calibrate up to 16 external capacitors with an accuracy of 1 part per million and a precision of 1 part per 100 million over a frequency range of 400 to 3000 Hz. At somewhat reduced accuracy, it can cover a range from 20 to 20,000 Hz. Its greatest range of capacitance is 0 to 1200 picofarads; auxiliary equipment may be added to extend this range to 100 microfarads.

Error-Compensation System for Computerized Machine Tools

As part of their study of measurement and control systems for automation, NBS researchers in the Center for Manufacturing Engineering developed a microcomputer-based error-compensation system for automated machine tools that has earned an I-R 100 award.

Most computer numerical-controlled (CNC) machine tools have software that automatically corrects for some positioning errors caused by the tool's cutter path drive system. But such corrections only account for errors along "one degree of freedom," whereas a typical CNC machine tool may have 20 or more degrees of freedom that contribute to geometric errors. The NBS error-compensation system calculates the positioning error associated with a particular location of the cutting tool based on a prerecorded "error map" of static positioning errors. In addition, the temperature of various parts of the machine tool provides a key to thermal positioning error. The position of the tool's cutting edge relative to the machine's coordinate system is provided by an automatic tool-setting station which is part of the system. All three elements are used by the system to provide real-time error corrections.

The system has been tested on two different commercial machine tools, in conjunction with two different controllers, demonstrating accuracy enhancements of 8 to 10 times over parts machined without error compensation. It also makes it possible to eliminate the machine-tool warm-up period—up to 10 hours of unproductive operation—that was previously required for precision machining.

The CNC machine tool error-compensation system was developed by Kang Lee, Thomas Charlton Jr., Dr. James Shaver, Ralph Veale, and Bruce Borchardt of NBS, Dr. Alkan Donmez and Professor Richard Liu of Purdue University, and William Zinn of Hardinge Brothers.

50-Kilohertz Phase Angle Standard

Dr. Raymond S. Turgel, a physicist in the NBS Center for Electronics and Electrical Engineering, received an I-R 100 award for his development of a standard for phase meters that improves the speed of calibrations 10 times or more. This device is designed to ensure reliable measurements of phase in applications such as testing aircraft navigational instruments, tracking satellites, and checking the operation of electrical power lines.

Turgel's invention works by creating two precision sine waves with frequencies from 2 Hz to 50 kHz, which are generated so the phase angle between them is known precisely and is adjustable in steps of 0.002 degrees up to 5 kHz and in steps of 0.005 degrees up to 50 kHz. Digital-to-analog converters are used to generate the analog output signals, and the phase angle is determined from the sets of calculated values used for the digital signal synthesis, but is not dependent on reactive elements or frequency.

The microprocessor-based calibration standard is virtually drift free due to the inherent high stability of the device's crystal-controlled digital synthesis circuitry. The digital synthesis technology developed for the invention forms the basis for further developments in precision waveform generation.

Pictured here from the left are Ralph C. Veale, Bruce R. Borchardt, James R. Shaver, Alkan Donmez, Thomas Charlton, Jr., and Kang B. Lee who received an I-R 100 award for developing an advanced error-compensation system for computerized machine tools. (Not present are C. Richard Liu and William Zinn.)

The development of an 50-kilohertz phase angle standard by Raymond S. Turgel merited an I-R 100 award.

'Assets' Frozen as Researchers Put Pollution Problems on Ice

It's an idea as old as the hills: Freezing preserves things.

Now scientists at the National Bureau of Standards are putting this age-old chilling practice to use in the laboratory as they preserve hundreds of human tissue and environmental specimens by freezing them at liquid nitrogen temperatures (about −150 °C). The result is a "bank" in which frozen "assets" (specimens) are deposited regularly and withdrawn any time interest accumulates in a particular chemical element or pollutant compound.

"The bank is especially valuable for determining pollutants present in the environment at a given place and time," says Dr. Stephen A. Wise, manager of the NBS specimen bank program. He adds that by having a frozen specimen on hand—a human liver donated from an autopsy, for example—scientists can analyze the organ tissue and construct a "picture" of chemicals the person had been exposed to until the time of death. The liver is a particularly good indicator of individual exposure to pollutants because it acts as a sponge in which toxic—and beneficial—chemicals collect.

The beauty of a cold storage system like NBS' prototype specimen bank is that if a new pollutant is discovered sometime in the future, specimens gathered years before can be retrieved and analyzed for this component. Researchers then can establish a "yardstick" that future analyses can be compared to, which would indicate exposure to that pollutant across the population and over a period of years. Depending on how long specimens had been banked, it might even be possible to determine exactly when and where a particular pollutant entered the environment.

NBS has banked human livers yearly since 1980 when its so-called Pilot National Environmental Specimen Bank was launched in cooperation with the Environmental Protection Agency (EPA). The Bureau gets its human livers in 200-gram samples—about the size of a fist—from autopsies conducted by state examiners' offices. Records about the donor's sex, age, occupation, and other factors are included whenever possible to give NBS researchers clues about what to look for in chemical analyses. For example, if a person was a heavy smoker, this will probably show up in the liver's chemical composition.

NBS has developed an elaborate protocol (procedure) for banking liver samples. It begins in the autopsy room, where the more common stainless steel knife of the medical examiner is replaced with a special titanium knife to minimize sample contamination. Livers are then placed in Teflon bags, again to minimize the contamination that could bias a chemical analysis, and shipped to NBS at liquid nitrogen temperatures. Back in the lab, Bureau scientists use a special "clean room" and Teflon containers to keep any outside impurities to a minimum.

...if a new pollutant is discovered sometime in the future, specimens gathered years before can be retrieved and analyzed for this component.

Some aspects of the Bureau's protocol were initially viewed with skepticism by other researchers, says Wise. "We got a few laughs from the scientific community in our early days when we insisted on the use of titanium knives and Teflon containers. But we've been so successful with these materials, other scientists are starting to use the same approach."

As NBS researchers have analyzed the livers, they've noticed certain trends. One of these is that environmental lead contamination appears to be declining. This study, however, is only in its early stages and requires further data before any firm conclusions can be made.

Another trend showed up in a recent study of 30 banked liver samples from a broad spectrum of donors. NBS found traces of eight widely used pesticides, including the notorious DDT, in all the livers, leading Bureau researchers to speculate on just where these materials came from. "We initially thought we'd find high levels of pesticides for our study in an older farmer who might have been exposed to them over a number of years when his crops were sprayed," Wise says. "But we looked at a farmer's liver and his levels really weren't that high. So we suspect that the reason all the livers have some degree of exposure is that the pesticides were absorbed through the food chain." Wise adds that though some pesticides have been banned or restricted in this country, the same materials are still used on crops in some foreign countries, and some of those foods are imported into the United States.

Another part of the initial NBS/EPA specimen bank project was the storage of several thousand marine mussels gathered from the Narragansett Bay area of Rhode Island. Because mussels collect impurities in the aquatic environment, they are considered good indicators of marine pollution.

The NBS facility also is being used as a repository for environmental samples taken from coastal areas around the United States. The National Oceanic and Atmospheric Administration

(NOAA), which is examining marine pollution through the banking of fish (croaker), mussels, and sediment samples, has funded NBS to develop protocols and to collect and bank some of the samples. One of the goals of the NOAA project, known as the National Status and Trends Program, is to establish a small bank of "reference samples" at NBS that can be compared for accuracy to those stored at NOAA's own facility.

Though the bulk of attention in the last 5 years has been on banking and analyzing human and marine samples, the NBS facility was also designed to store specimens that are environmental accumulators of food and air pollutants. Milk and grain are typical indicators of food contaminants and moss or lichen are good absorbers of air pollution. Though these samples have not been banked yet, a new cooperative program between NBS and several other agencies has opened the door to the banking and analysis of food samples.

Dubbed the Coordinated Research Program on Human Daily Dietary Intakes of Nutritionally Important Trace Elements, the project is a mammoth undertaking to determine the constituents that make up typical meals in a worldwide cross section of countries. Bringing together NBS with the Department of Agriculture, the U.S. Food and Drug Administration, and the International Atomic Energy Agency (based in Vienna, Austria), the program aims to map what's good and bad in the American diet and those of 11 other countries (Brazil, China, Iran, Italy, West Germany, Sudan, Turkey, Spain, Thailand, Canada, and Sweden).

A typical day's meal including, for example, a breakfast consisting of bacon, eggs, toast, and coffee will be blended together—homogenized—and then analyzed for chemical makeup," says Dr. Rolf Zeisler, an NBS chemist who is a coordinator of the project. Researchers will be looking for accurate levels of more than 20 nutritionally important elements, as well as for a few of the environmental pollutants that have entered the food chain. NBS will contribute to the project by storing some of the food samples in the specimen bank, by developing protocols for handling and homogenizing the food specimens, and by lending the expertise of its chemists to help analyze the samples. At a gathering of the project participants earlier this year, representatives agreed that the program, among other things, will result in confirmation or revision of the Recommended Daily Allowance (RDA) of various nutrients—a list of numbers represented on virtually every packaged food product sold in this country.

Other projects have been discussed for the specimen bank, such as storage of human adipose (fat) tissue for EPA, which is interested in levels of such components as dioxins. NBS also will be banking samples of human blood serum to measure nutrients in a program for the National Cancer Institute that aims to determine the role vitamins play in preventing tumors. And a pollution study of the Chesapeake Bay is in the early planning stages.

The NBS specimen bank is not the only one in the country. In fact, stored samples elsewhere helped establish when the pesticide kepone first entered Virginia's James River in the 1970's. A 1980 Canadian study used herring gull eggs banked for 9 years to identify a decrease in dioxin pollution in the Great Lakes. There also is a huge specimen bank project under way in West Germany, one that began about the same time as the Bureau's. NBS and German scientists get together regularly to compare notes on their banking experiences.

Kathy Fitzpatrick (left) and Susan Stone load a human liver specimen into a liquid nitrogen storage tank.

So while the specimen bank idea is not a new one, the NBS project was the first national pilot program with the goal of determining the feasibility of such banks and for establishing the elaborate protocols and handling procedures for samples.

"One of the problems we had when we started out," says Wise, "was getting across the idea that the real benefits of banking specimens are way off in the future. It's not something that has immediate results. But I think we've shown that these facilities work. And while we'll probably always serve as a facility for banking mainly someone else's samples, we're going to continue to refine our techniques and pass these ideas on to other specimen bank users."

by John Henkel
NBS Public Affairs Specialist

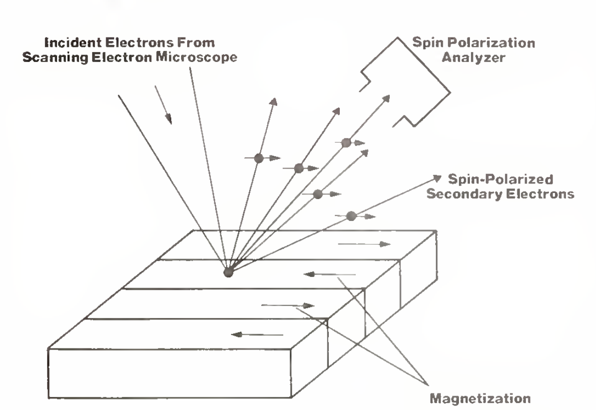
New Instrument Allows Observation of Surface Magnetic Microstructure

Researchers at the National Bureau of Standards have developed a technique for observing—simultaneously—the magnetic character of a surface and its physical structure over dimensions as small as 100 angstroms.

The new research tool is expected to have important applications in a number of fields, including the development of high-density magnetic recording media and small, high-efficiency electric motors. It was designed by Drs. John Unguris, Daniel Pierce, and Robert Celotta of the NBS Center for Radiation Research and Dr. Gary Hembree of the NBS Center for Manufacturing Engineering.

The technique weds an ultra-high-vacuum, high-resolution scanning electron microscope (SEM) with a new, compact electron spin-polarization detector developed at NBS. By measuring the secondary electron spin polarization, the resulting instrument images directly the magnitude and orientation of the magnetic structure of materials with a resolution far better than the best current instruments, while simultaneously producing a conventional SEM image of the surface.

How polarization analysis works



A scanning-type electron microscope "scans" a tightly focused beam of electrons across the surface of the object under study. The actual magnified image is derived from secondary electrons that are emitted from the object under the action of this beam. The spin orientations of the electrons in the original beam are random, but the spins of the secondary electrons reflect those of the electrons in the surface being probed. (The spins of the secondary electrons are in the opposite direction to the magnetization as a consequence of the mathematical definition of magnetization.)

The magnetism of an object is essentially a measure of the net electron spin density in the material. Electron spins in nonmagnetic materials have random orientations; in materials with some degree of magnetism, more spins are oriented in one direction than in the opposite direction yielding an "electron spin polarization."

Not all of the electrons in a magnetic material are oriented in the same direction, however. Typically, the material contains regions or "domains" in which there is a preferred direction along which the electron spins are oriented; the preferred directions may vary from one domain to another. An important feature of this new technique is that, since the SEM beam probes regions smaller than the domain size, it is possible to view the magnetic domains with very high spatial resolution.

Exactly how the domains are magnetized and what relationship the surface topographic and chemical features bear toward the arrangement and distribution of the surface magnetic domains are key factors in a number of important magnetic materials.

Examples include high-density magnetic recording media for computers; new, strongly magnetic alloys for use in small, high-efficiency electric motors; and communications devices.

A key element in the new NBS instrument is a low-voltage electron spin detector. Previous spin detectors (Mott detectors) operate at about 100,000 volts and require at least a cubic meter of space and special high-voltage precautions. The new detectors, which operate at about 150 volts, will fit in a cube about 6 cm on a side and are at least as efficient as an optimized Mott detector. The detector relies on the spin-dependent scattering of the electrons from an evaporated polycrystalline gold film.

Shown are magnetic domains imaged using an SEM fitted with the NBS electron spin-polarization analyzers. The light and dark regions correspond to areas of opposite magnetization. The material is an Fe-Si 3 percent single crystal and the picture dimensions are about 50 micrometers by 50 micrometers.

The polarized SEM is based on research results reported by NBS in 1982 which demonstrated that the secondary electrons which are emitted by targets struck by an electron beam retain the spin polarization of the region of the surface from which they originate.

NBS would like to set up collaborative research programs with industrial and academic labs to exploit the potential of this new instrument. Interested researchers are invited to contact Dr. Robert Celotta, B206 Metrology Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2051 for further information.

by Michael Baum
NBS Public Affairs Specialist

Open Systems in Software

Once the excavators, the bricklayers, and the carpenters are finished, they leave behind a framework. Then come the plasterers, the finishers, and the decorators, and they turn the framework into a house.

Likewise, once the designers of a computer system, or an entire network, have put in place the hardware and procedures—the framework—needed to permit one part to talk to another part, the software people have to give the system something to say.

Structure and Function

The makers of a house or other mechanical/electrical system can rely on standards, both formal and informal—standard materials, standard design specifications, standard procedures—to help them with both structure and function. But when it comes to computer systems, until very recently builders have had to go it alone, from cutting and sizing the lumber to figuring out how to drive each nail. That's not very efficient.

And that's why standards for networking and software, the structural and functional aspects of integrated computer systems, are high on the Most Wanted List of three sets of people: systems builders, like Boeing and TRW, who assemble integrated and embedded computer systems; major vendors of computer equipment and software; and large-scale computer users, like the U.S. government. Successful network and software standardization will result in "open" systems, that is, computer systems which can be used to exchange information worldwide to facilitate daily commerce.

"The systems builders may build multimillion-dollar systems, like a space shuttle, and the hardware and software get very complicated very quickly," explains Helen Wood, head of the National Bureau of Standards' Information Systems Engineering Division. "They need to solve complex problems, but like many computer users, they're faced with the need to use equipment from one manufacturer that may be the best hardware solution for the problem, but it won't talk to another piece of equipment made by somebody else. Then, they have to have software for, say,

...the Bureau's computer institute "is uniquely situated to be an effective, impartial negotiator in the standards development process."

navigation, but it won't talk to the software that handles engine-separation systems."

In other words, compatibility, or the lack of it, is two-tiered: It is located in both the structural tier and the functional tier of the system. Helen Wood's concern is functional compatibility, the software.*

NBS Standards Not Regulatory

Wood, as a manager in the NBS Institute for Computer Sciences and Technology (ICST), directly represents the federal government's interests, as a major user of computer systems, in computer-standards development. ICST is empowered by Congress to develop Federal Information Processing Standards, called FIPS, and guidelines for use by government agencies in planning, purchasing, and using computer systems. Wood stresses, "We strive to ensure that FIPS are consistent with voluntary national and international standards wherever possible."

The Bureau's success in getting industry to support its computer standards comes not from regulatory powers, which it does not have, but from two other factors: the collective clout of federal purchasing power—government agencies spend some $14 billion a year on computers and related equipment and services—and NBS' "leveraged" position in the computer community.

Vico Henriques, president of the Computer and Business Equipment Manufacturers Association, recently described this position for Congress. Henriques told members of a Senate subcommittee in March that NBS has expertise and facilities for standards development unmatched elsewhere in the world; that unlike a company with proprietary self-interests, NBS' impartiality can be—and is—trusted; and that, therefore, the Bureau's computer institute "is uniquely situated to be an effective, impartial negotiator in the standards development process. It promotes voluntary international standards that preserve U.S. industry's competitive positions in the world market, while supporting users' needs for standards to achieve increased productivity and delivery of services at reduced cost."

NBS Aims: Increased Productivity, Reduced Cost

NBS' Helen Wood stresses that software standards can mean productivity gains and cost savings to government computer users and to the entire computer community of systems builders,

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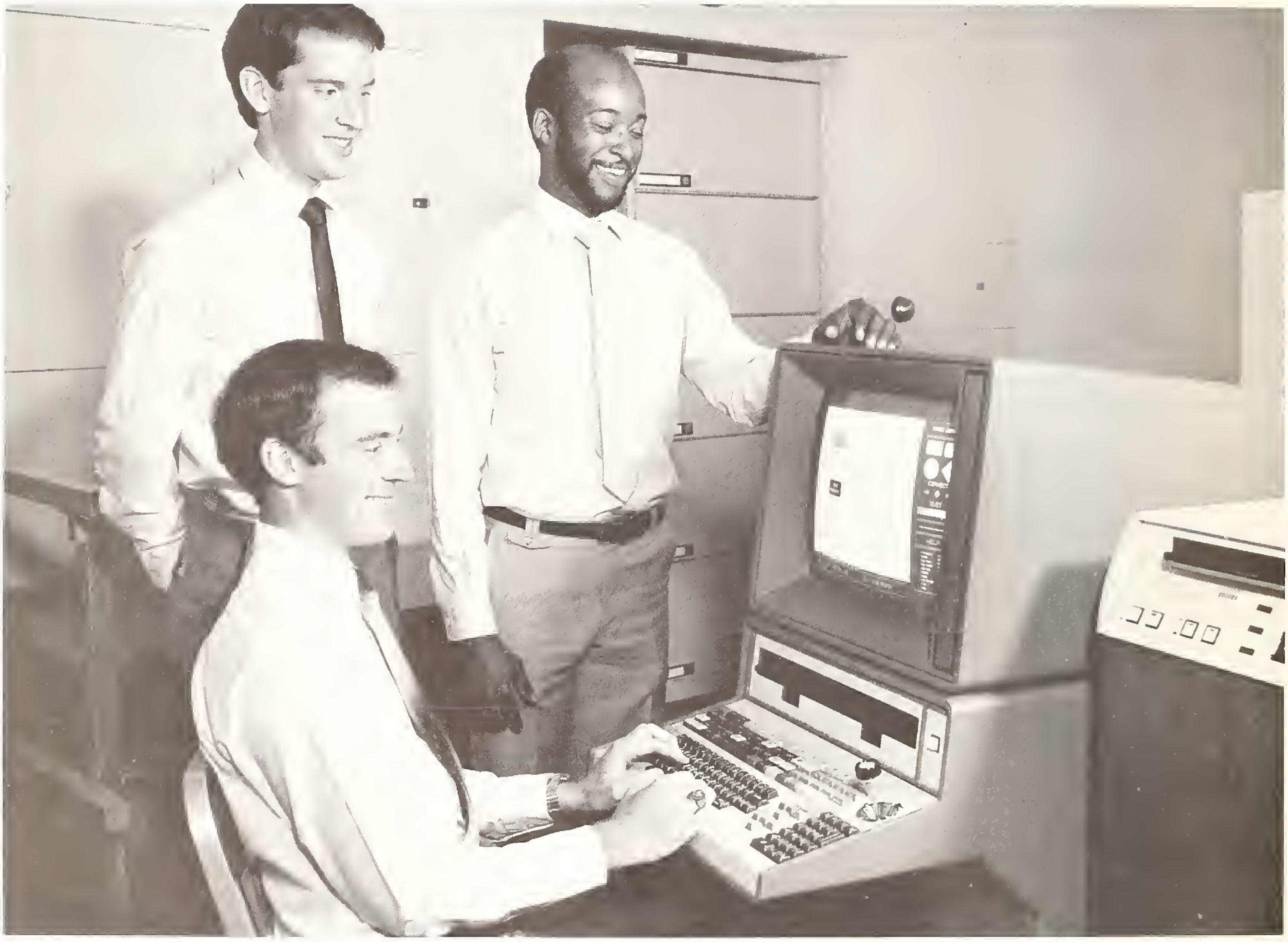
* Others at NBS are concerned with structural compatibility. See *NBS Research Reports* on computer networking standards, called "Welcome to the New Computer Age: The Era of Networks," published in February 1985.



Charles Sheppard, a manger in the NBS computer-graphics area, and summer student Bill Youstra (standing) watch as Ray Youstra, also a student, works with the NBS-developed logical database design graphics model.

vendors, and users. "Our database management standards alone are expected to save the government some $265 million," she says. "But I'm not talking about standardizing proprietary products," she hastens to add. "I'm talking standards for assuring that every database program can carry out essential functions and standards for easing integration between one program and another."

In other words, to save time and greatly increase the efficiency of human and machine, both data and trained users should be "portable" from one database management system to another and conversion from one such system to another should be easy.

Wood explains: "Database management systems are programs that define data by classifying them and manage data by storing, recalling, and analyzing them. When you ask the same question on two different DBMS's, against the same collection of data, you want to get the same answer. If those two DBMS's say they conform to the same standard, that should be your guarantee that you will get the same answer.

"Just think. You don't have to limit yourself to using a single program or set of programs or even a certain kind of hardware if you have a standard that is widely used. And think of the time and money to be saved in training. You should be able to do the same standard operations with different software and hardware systems without retraining."

The same sorts of benefits will accrue from the use of standardized approaches to computer graphics, Wood claims. But not yet, in either case. Software integration is presently accomplished only by expensive ad hoc programming efforts, unless a piece of software is part of a proprietary system of integrated programs. "But in 5 years we should see open systems in all kinds of software," Wood claims.

The Bureau is working to make this expectation a reality, particularly for data management and graphics systems. Standards activities currently focus on standard programming-language formats for specifying essential data structures and operations; standard data-description formats into which data structured in proprietary formats can be converted for transfer to other systems; a standard Data Dictionary System which specifies the most commonly needed facilities of systems used to describe and define data; and graphics programming standards.*

Wood points with pride to successes in each of these areas. "We are particularly pleased with the collaborative work we do with the NBS Automated Manufacturing Research Facility [AMRF] where we can performance test our standards and work with them on specific data management and graphics needs," she says. The AMRF is the Bureau's automated flexible manufacturing facility—a research center for studying the computer-controlled machine shop. Researchers are developing modular control systems that can use the same database to accomplish different tasks via programmable robots. It is an effort to produce an efficient standard control structure for flexible automated manufacturing systems of virtually any type, differences in proprietary hardware and software notwithstanding.

The Information Systems Engineering Division and AMRF are also collaborating on a Defense Department (DOD) project, Wood says: "Neither of us could do it alone. It is just a single instance of the pressing overall need for open-systems software and hardware. What DOD needs is a computer-aided logistics support system. In other words, how do you move people, supplies, and equipment around, keep track of all of it, and manage it all at the same time? That's what they want to know. If something breaks, for example, how does somebody find out how to fix it? Manuals go out of date and must be updated. That's a lengthy process. What if, instead, all the information is in computerized form and instantly available. A change in a manual, or any other change, would reverberate through the system immediately. We're working on that project right now."

"Our database management standards alone are expected to save the government some $265 million."

As Wood emphasizes, NBS is responsible not only for standards but also for the supporting test methods. "Test methods are needed both during development of standards and to prove product conformance once standards are in use," she says. "That means you have to develop a testing program that puts a software package through its 'standard' paces. We're doing that for both data dictionaries and graphics programming software."

Data Dictionary

David Jefferson manages the NBS database standards programs, including the data dictionary standard. "A database management system can support many different applications, like payroll systems, accounting systems, and so on," he says. "Often those applications have to be specially programmed [they aren't bought off-the-shelf]. So, you need a source of information for controlling all the steps in producing and using a database application. A data dictionary is that control. It defines the terms used in a database system, like record, or set, or price, or whatever, and the semantic relationships among them.

"Also, like a real dictionary, it may give you synonyms and a textual explanation of what things mean. Or it may only give you a very basic meaning. For example, it may only tell you that a Social Security number is nine digits—and nothing about what it's for or how it's used. But it may also give several definitions for price, such as base price, sales price, and the like. You see, one of its major tasks is to facilitate the use of very precise data among people. This function also resolves conflicts between two programs that use different definitions for the same terms."

Another function of a data dictionary, Jefferson explains, is a directory function. "This tells you that a record or whatever is in a particular place and instructs you how to get it. When you're searching for something, this

* A complementary standards activity elsewhere at NBS involves the Initial Graphics Exchange Specification, or IGES. IGES provides a format for the 3-dimensional parts models typical of computer-aided design systems. It can be used in conjunction with the standards described in this article.

NBS Wants Software Companies for Testing Program

Participation Will Help Companies Develop Standard Software Products

Producers of computer software are invited to join other software companies and the National Bureau of Standards in software-testing programs related to emerging national and international software standards.

The accompanying article reports on developments at NBS in computer software standards, particularly those for data dictionary systems and computer graphics. These and other standards activities in the areas of database management systems, programming languages, operating systems, and document interchange are complemented by NBS programs for testing standardized software.

The testing programs aim at providing techniques that can ultimately be used in private laboratories to determine whether a specific software product conforms to a particular software standard. Participating companies will work with NBS researchers to design, develop, and evaluate test procedures. NBS will provide available documentation, prototype implementations, and laboratory testbeds.

For information on how to participate in one or more of these programs, write or call Helen Wood, A255 Technology Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-3553.

saves time. And it can do other things. It can tell you how data interact with other things. Say you have several zip-code-using programs, like a personnel data system and a payroll system and whatever. A data dictionary can tell you what programs and what files contain zip codes, so if you need to change zip codes, you know where to go. In fact, it can inventory an entire information resource, including files, programs, and hardware."

A data dictionary isn't just a passive tool either. It can limit access to programs and files. This function is of major importance, whether the data in question are sensitive, as in programs related to national security, or simply private, as in medical records.

Over the past 3 years, NBS has worked with computer users and vendors to develop a standard for a Data Dictionary System; the DDS is now a draft FIPS standard containing specifications for selecting, evaluating, and procuring data dictionary software. Software which satisfies the standard will make the contents of database systems more portable, from program to program and from one piece of hardware to another. It will also make skills more portable, because computer personnel will not have to learn a new language and procedure every time they use a different piece of data dictionary software. Such portability is expected to save the government more than $135 million* over the first 5-6 years of use.

The NBS Data Dictionary System has been adopted by The American National Standards Institute (ANSI) as the basis for a proposed national standard. In addition, the International Organization for Standardization (ISO) is considering these specifications as an international standard. One research associate from industry is already at work helping NBS design and develop conformance tests for the proposed DDS standard (see box).

Computer Graphics

In the NBS Information Systems Engineering Division, Mark Skall manages the work in graphics standards. He says his group began a study in June 1983 to find out what federal agencies were doing as far as the use of computer graphics is concerned and to determine what they needed for understanding how to buy and use graphics programs. As a result of the study, NBS is pursuing the development of several graphics standards and is working on related conformance testing and measurement techniques for graphics software.

The study revealed a particular need for a programming standard for 2-dimensional graphics. Agencies were using different packages to write graphics applications and when they tried to exchange applications, they had

* This amount is part of the $265 million mentioned earlier.

to reprogram. Programmers wanted a 2-dimensional graphics standard for producing portable graphics applications. Computer users in the government also wanted to be able to transfer just pictures, rather than whole programs.

The first need can be satisfied by an ANSI and ISO proposed standard known as the Graphical Kernel System (GKS), which was developed originally by the GMD, a German government organization. It is being processed by ICST as a FIPS. The need for picture transfer will be met by a standard called Computer Graphics Metafile, also being developed in ANSI and ISO. It, too, is being processed as a FIPS.

NBS has been instrumental in fine-tuning these and other national and international graphics standards to make them fully functional. For example, in regard to GKS, "what was missing was a standard way to access graphic functions from different programming languages," Skall says. "So I chaired an ANSI subcommittee that developed bindings to the graphics systems from different programming languages. We picked the languages most requested by the computer users we surveyed. They named FORTRAN, C, PASCAL, and ADA. The technique we produced is the same for every language, so if someone is trained to use the graphics standard with FORTRAN, his skill is transferable to the other languages."

Additional ANSI/ISO graphics standards under development, with NBS support, are a standard for 3-dimensional graphic functions and a computer graphics interface for hardware and software. ICST intends to process these standards as FIPS when they are completed.

Flanking Helen Wood in this picture are Patricia Konig and Dr. Alan Goldfine, the NBS researchers most directly involved with the NBS data dictionary system.

Other projects include work with industry to get the standards into off-the-shelf products and to develop tests for conformance to the standards. Skall's group is setting up a comprehensive graphics laboratory for the development and use of effective testing techniques. They have also signed an agreement with the GMD to coordinate U.S. evaluation of the GKS conformance tests under development in Europe.

Wood says the key feature of NBS' approach to software standards is interaction—interaction with the government community the computer institute serves, interaction with domestic computer-related corporations, and interaction with the national and international standards-making community.

"We welcome cooperative research efforts with American companies through such mechanisms as the NBS Research Associate Program, and we bring in standards expertise through the Guest Worker Program," she says. "We want to see standards used to enhance fair competition in computer software worldwide. Right now this country produces 70 percent of the world's software. Other countries will naturally take a bigger share of that market in the future. But we don't want to lose our competitive edge by turning our backs on standards while other nations forge ahead. We must stay in front in the standards game." J.C.

HELP IN DESIGNING DATABASES

Fong, E.N., Henderson, M.W., Jefferson, D.K., et al., ***Guide on Logical Database Design,*** *Natl. Bur. Stand. (U.S.), NBS Spec. Pub. 500-122, 115 pages (February 1985). Order by stock no. 003-003-02631-0 from GPO, $4.50 prepaid.*

An information system is only as good as the database which supports it; a poorly-designed database can lead to time-consuming and expensive software revisions as needs change. To help avoid this, NBS has developed a guide to enable managers, systems analysts, and applications programmers to plan for an information system that will fulfill both present and future needs. This publication suggests that a database be designed in four phases during which all the subsystems within the system, the data flows, data structures, and user needs are described. The guide is intended to help design very large, complex information systems which are meant to be used for a long time.

FIELD STRENGTHS IN COMPLEX ENVIRONMENTS

Kanda, M., Randa, J., and Nahman, N.S., ***Possible Estimation Methodologies for Electromagnetic Field Distributions in Complex Environments,*** *Natl. Bur. Stand. (U.S.), NBS Tech. Note 1081, 52 pages (March 1985). Order by stock no. 003-003-02638-7 from GPO, $2 prepaid.*

Electromagnetic (EM) pollution is a fact of life today; there is a complex matrix of electronic equipment operating in a complex EM environment. As a result, the estimation of the maximum EM field strength in a given area is very important in addressing many interference problems such as the penetration of EM waves into buildings that house sensitive electronic and ordnance equipment. This report outlines three approaches to estimating EM field distributions in complex environments: 1) statistical treatment of the spatial distribution of EM field intensities; 2) a numerical computation using a finite-element form of the EM action functional; and 3) use of a directional probe to scan a volume.

GUIDE TO IMPROVED QUALITY ASSURANCE

Taylor, J.K., ***Principles of Quality Assurance of Chemical Measurements,*** *Natl. Bur. Stand. (U.S.), NBSIR 85-3105, 80 pages (February 1985). Order by stock no. PB 85-177947/AS from NTIS, $11.50 prepaid.*

This NBS report should help researchers and technicians interested in bettering the precision and accuracy of analytical chemical measurements—such as those needed in the compositional analysis of materials, process control, and regulatory enforcement. The publication is a condensed version of seminars NBS offers chemists, lab supervisors, and quality control professionals in the quality assurance (QA) of chemical measurements. Included are discussions of what QA is, quality control techniques, control charts, sampling methods, QA programs, protocols, and functions of a reference laboratory. For more information about NBS quality assurance seminars, contact Dr. John K. Taylor, 301/921-3497.

COMPUTER-AIDED DISPATCH SYSTEMS

Brenner, D.J. and Cadoff, M.A., ***Guide to Computer-Aided Dispatch Systems,*** *Natl. Bur. Stand. (U.S.), NBSIR 84-2991, 42 pages (March 1985). Order by stock no. PB 85-187565/AS from NTIS, $8.50 (microfiche, $4.50) prepaid.*

The NBS Law Enforcement Standards Laboratory has developed a "user's guide" for public-safety agencies and other organizations interested in buying or improving a computer-aided dispatch (CAD) system. CAD systems support dispatchers by providing an efficient system for responding to a citizen's complaint and tracking the progress of the responding units. Use of a CAD system improves the accuracy of information transmitted to the patrol officer and provides automatic database checks (cross-checks on location of incidents, for example), record-keeping, and report-generation. Prepared for the National Institute of Justice, the NBS guide discusses CAD system operation, hardware and software components, CAD system benefits, maintenance and repair, and the procurement process.

NEW ADDITION TO OPTICAL RADIATION SELF-STUDY MANUAL

Nicodemus, F.E., editor, ***Self-Study Manual on Optical Radiation Measurements: Part 1—Concepts, Chapter 12,*** *Natl. Bur. Stand. (U.S.), NBS Tech. Note 910-8, 44 pages (April 1985). Order by stock no. 003-003-02647-6 from GPO, $2 prepaid.*

NBS has published another section of this manual, a long-term project to produce a comprehensive guide to the theory and practice of making accurate measurements of optical radiation. The new section, "Chapter 12, Blackbodies, Blackbody Radiation, and Temperature Scales," by Joseph Richmond and Fred Nicodemus deals with the role of temperature in optical radiation measurements. This is the eighth volume in the Self-Study Manual series. Previous volumes examine a variety of topics in the basic measurement theory of optical radiometry, the calibration of radiometric instruments, and the specific application of that theory to some important solar irradiance measurements.

PERFORMANCE OF OSI TRANSPORT PROCEDURES

Mills, K.L., Gura, J.W., and Chernick, C.M., ***Performance Measurements of OSI Class 4 Transport Implementations,*** *Natl. Bur. Stand. (U.S.), NBSIR 85-3104, 52 pages (January 1985). Order by stock no. PB 85-177657/AS from NTIS, $10 prepaid.*

The NBS Institute for Computer Sciences and Technology has developed a system to measure whether computer equipment incorporating the transport protocol layer of the Open Systems Interconnection (OSI) Reference Model is performing according to the standards that have been developed by the International Organization for Standardization. The OSI Reference Model is a blueprint to make possible computer-to-computer communication. The transport protocol carries out the data communications function of assuring that data are not lost, duplicated, or corrupted in transit and that they get to their destination in the right order. This report describes the system and the measurements it can make.

CERTIFICATION PROCEDURES FOR STATE LABS

Oppermann, H.V. and Taylor, J.K., ***State Weights and Measures Laboratories,*** *Natl. Bur. Stand. (U.S.), NBS Hdbk. 143, 82 pages (February 1985). Order from Office of Weights and Measures, A617 Administration Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2401.*

This publication describes for industrial users of measurement laboratory services, including nuclear power plant operators and others, the procedures followed by NBS in certifying state weights and measures laboratories. A certified laboratory must satisfy general and specific requirements for each competence area. Competence includes a laboratory's management practices, test procedures, and the facilities that are available for performing reliable measurements, principally mass, volume, and length. This handbook contains procedures for authorizing certified laboratories to conduct evaluations of weighing and measuring devices and systems under the National Type Evaluation Program (NTEP), a one-time evaluation for new measuring devices. Under NTEP, NBS or one of the authorized state laboratories performs an evaluation for acceptance by all of the other states, thereby eliminating costly duplicate tests by each jurisdiction.

ASSESSMENT OF NUCLEAR POWER INDUSTRY'S MATERIALS DATA NEEDS

Rumble, Jr., J.R. and Westbrook, J.H. (General Electric Corporation), ***Computerizing Materials Data—A Workshop for the Nuclear Power Industry,*** *Natl. Bur. Stand. (U.S.), NBS Spec. Pub. 689, 44 pages (January 1985). Order from Dr. John R. Rumble, Office of Standard Reference Data, A323 Physics Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-3441.*

Designers and engineers for the nuclear power industry, which has more than a $100 billion investment in materials, are concerned about the retrofitting of existing facilities and extending the service life of materials that are in place. This publication reports on the conclusions and recommendations by participants at a special meeting sponsored by NBS, the Metal Properties Council, and other leading industry groups. Participants were asked to identify the types of materials property data that are needed and to determine how they will be used. The information was sought to help develop the National Materials Property Data Network, a joint industry/government effort to come up with a computerized "gateway" system for fast and easy access to various databases of validated data on the engineering properties of materials.

ANNUAL DIRECTORY OF ACCREDITED LABORATORIES

Berger, H.W., editor, ***1984 NVLAP Directory of Accredited Laboratories,*** *Natl. Bur. Stand. (U.S.), NBS Spec. Pub. 687, 79 pages (February 1985). Order from Harvey Berger, Associate Manager, Laboratory Accreditation, A531 Administration Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-3431.*

The eighth annual directory from the National Voluntary Laboratory Accreditation Program (NVLAP) lists approximately 120 laboratories nationwide that are accredited in one or more areas of testing. It includes a report on current program activities and the new NVLAP program procedures adopted in late 1984 to increase efficiency and reduce costs. Currently, there are voluntary laboratory accreditation programs for thermal insulation, ready-mixed field concrete, carpet, solid-fuel room heaters, acoustical testing services, personnel radiation dosimeters, commercial products (paper and paper products, paints and related coatings and materials, and mattresses), and photographic film.

FORECAST OF TELECOMMUNICATIONS TECHNOLOGY

Kay, P. and Powell, P., editors, ***Future Information Technology—1984 Telecommunications,*** *Natl. Bur. Stand. (U.S.), NBS Spec. Pub. 500-119, 337 pages (December 1984). Order by stock no. 003-003-02626-3 from GPO, $9.50 prepaid.*

Telecommunications technology is the focus of this report, compiled and edited by NBS. It includes a telecommunications forecast through 1999, three perspectives on the divestiture of AT&T, a discussion of how changing technology will affect computer security, and how management will be affected by trends in information technology. The report also summarizes an industry workshop held in September 1984 at NBS that discussed trends in telecommunications technology.

DIRECTORY OF CERTIFIED STATE WEIGHTS AND MEASURES

Oppermann, H.V., ***State Weights and Measures Laboratories—Program Description and Directory,*** *Natl. Bur. Stand. (U.S.), NBS Spec. Pub. 686, 69 pages (January 1985). Order by stock no. PB 85-137651 from NTIS, $10 prepaid.*

Defense contractors, pharmaceutical manufacturers, nuclear power plant operators, food processors, petroleum distributors, and others who must verify that their measurements standards are traceable to NBS will be interested in the new directory of state weights and measures laboratories that are certified by the Bureau. As a part of its mission to promote uniform standards of measurement, NBS trains state metrologists in test procedures used in NBS laboratories and conducts a voluntary certification program for state laboratories. The directory is in two parts: Part I describes certified areas of measurement and requirements for laboratory certification; Part II lists state measurement laboratories and the services they provide to state and local weights and measures agencies, as well as those that are available to industry.

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

Workshop on Electrical Measurement Assurance, Ramada Hotel O'Hare, Rosemont, IL

October 27-November 1, 1985

This intensive 5-day workshop will provide in-depth training for those involved in d.c. and low-frequency electrical measurements. Participants will receive instruction based on techniques used in the Electricity and Statistical Engineering Divisions of NBS. The objective will be an understanding by participants of how to establish and maintain rigorous quality control programs in their own laboratories to ensure the accuracy of electrical measurements. Sponsored by NBS. Contact: Dr. Arthur McCoubrey, B160 Physics Building, NBS, Gaithersburg, MD 20899, 301/921-3301.

Workshop on Test Procedures for Precision Instrumentation and ATE Systems, NBS, Gaithersburg, MD

November 5-6, 1985

At this workshop, researchers, users, manufacturers, testing companies, and calibration laboratories will exchange information on the procedures used in testing the performance of precision instrumentation and ATE systems. Topics to be discussed include first article/acceptance testing, bid sample testing, maintenance/calibration testing, test accuracy ratios, economic tradeoffs of testing, case histories of specific test programs, optimum calibration strategies, and recommended practices. Sponsored by the Institute of Electrical and Electronics Engineers and NBS. Contact: John R. Sorrells or Barry A. Bell, B162 Metrology Building, NBS, Gaithersburg, MD 20899, 301/921-2727.

Factory Standards Conference, NBS, Gaithersburg, MD

November 20-21, 1985

Individuals from universities, research laboratories, and industrial organizations will discuss the issues associated with the design and implementation of factory models for automated manufacturing systems. In addition, attempts will be made to identify potential areas for standardization for these systems. A test run of the Automated Manufacturing Research Facility will be held in conjunction with the meeting to demonstrate the capabilities of this manufacturing research testbed. Sponsored by NBS. Contact: Dr. Albert Jones, A127 Metrology Building, NBS, Gaithersburg, MD 20899, 301/921-2461.

Power Semiconductor Devices Workshop, NBS, Gaithersburg, MD

December 5, 1985

Designed for professionals actively working in the field of power semiconductor devices, this workshop will be held in conjunction with the 1985 IEEE International Electron Devices Meeting in Washington, D.C. All attendees will be expected to be active participants and come prepared to help develop responses to specific questions that will address particular topic areas. Sponsored by NBS and the Institute of Electrical and Electronics Engineers Electron Devices Society. Contact: David L. Blackburn, B310 Technology Building, NBS, Gaithersburg, MD 20899, 301/921-3621 or Sandy Kelley, B344 Technology Building, NBS, Gaithersburg, MD 20899, 301/921-3541.

Workshop on Measurement of Electrical Quantities in Pulse Power Systems—II, NBS, Gaithersburg, MD

March 5-7, 1986

The purpose of this workshop is to disseminate information on modern measurement techniques, define the state-of-the-art of measurement of electrical quantities in pulse power systems, and identify areas in which improvements in measurements are required. Papers will be presented on voltage, current, power, and energy measurements; data acquisition and processing; and calibration methods for laboratory and machine use. Organized by NBS. Contact: John R. Sorrells, B162 Metrology Building, NBS, Gaithersburg, MD 20899, 301/921-2727 or Dr. Ronald H. McKnight, B344 Metrology Building, NBS, Gaithersburg, MD 20899, 301/921-3121.

CPEM 86, NBS, Gaithersburg, MD

June 23-27, 1986

CPEM 86 is the world's premier international conference for those in the fields of electromagnetic metrology and related fundamental physical constants. Papers describing original work, not previously published or presented, covering the theory, design, performance, simulation, or application of electromagnetic standards, measurements, techniques, instruments, or systems, are sought. The following fields are considered to be especially appropriate: EM-related fundamental constants and standards; direct current, low frequency, and RF; time, time-interval, and frequency; antennae and fields; microwaves and millimeter waves; infrared, visible, and ultraviolet radiation; lasers; electro and fiber optics; cryo-electronics; automated measurements; and technical calibration services. Sponsored by the Conference on Precision Electromagnetic Measurements. Contact: Norman Belecki, B146 Metrology Building, NBS, Gaithersburg, MD 20899, 301/921-2715.

The National Bureau of Standards 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 Institute for Materials Science and Engineering.

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 areas:
- Standard Reference Data
- Measurement Services
- Basic Standards
- 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
- Manufacturing Engineering
- Building Technology
- Fire Research
- Chemical Engineering

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 INSTITUTE FOR MATERIALS SCIENCE AND ENGINEERING

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 institute consists of the following divisions:
- Nondestructive Evaluation
- Inorganic Materials
- Fracture and Deformation
- Polymers
- Metallurgy
- Reactor Radiation

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