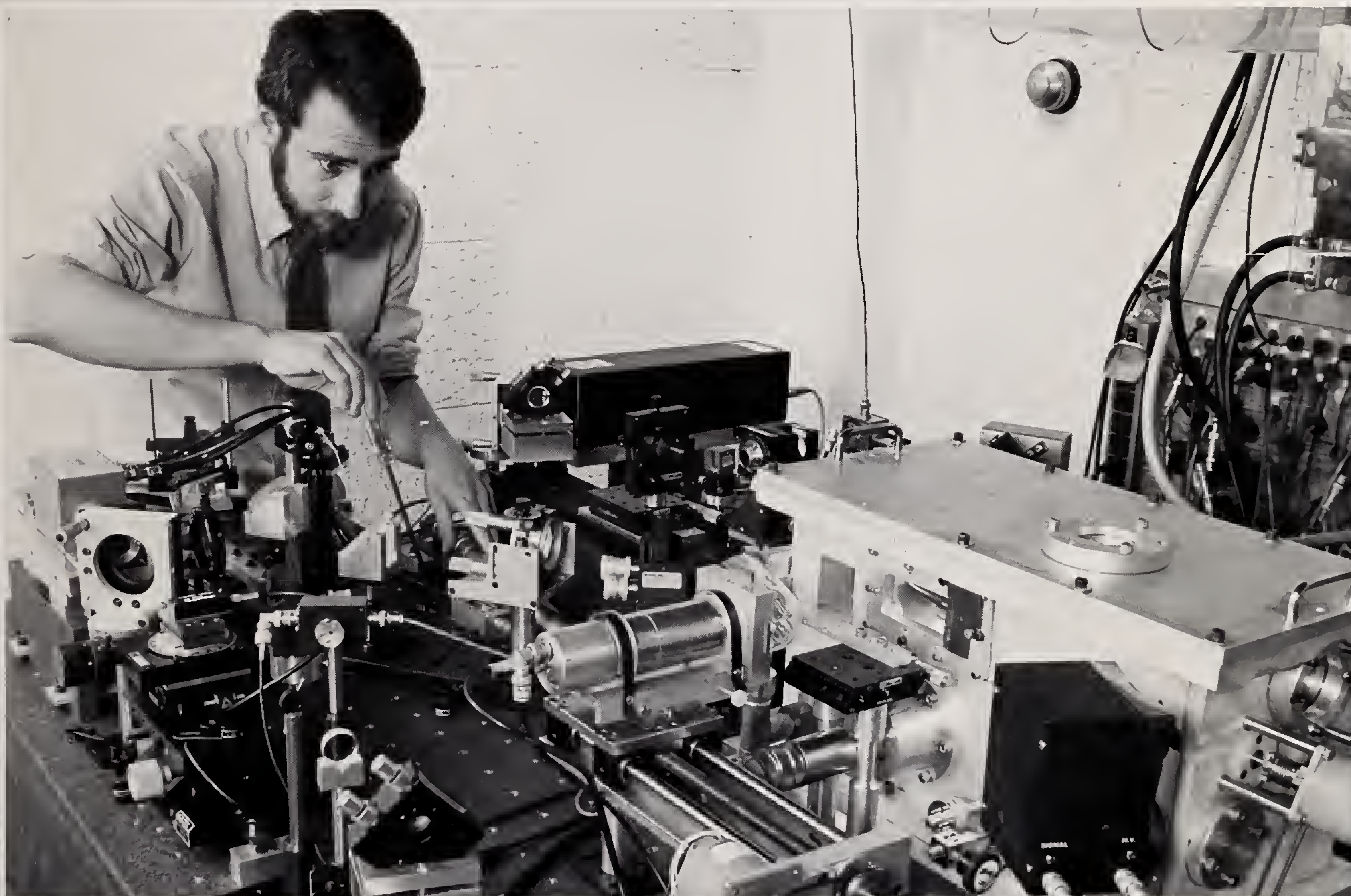
NATIONAL BUREAU OF STANDARDS

NBS Research Reports



U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
NBS SPECIAL PUBLICATION 735

Cover photo: NBS physicist Geoffrey Greene adjusts an x-ray interferometer for measuring the spacing of the planes in silicon crystals—a sort of atomic-scale ruler. **See article on page 5.**

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NBS Research Reports

U.S. DEPARTMENT OF COMMERCE
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Gaithersburg, MD 20899
301/975-2000

National Bureau of Standards
Boulder, CO 80303
303/497-3000

December 1987

NBS Special Publication 735
Prepared by the Public Information Division
A903 Administration Building
National Bureau of Standards
Gaithersburg, MD 20899
301/975-2762

Library of Congress
Catalog Card Number: 87-619882

CODEN:XNBSAV

GROUND BROKEN FOR COLD NEUTRON RESEARCH FACILITY

On November 20, Deputy Secretary of Commerce Clarence J. Brown, NBS Director Ernest Ambler, and Rep. Connie Morella (Md.) broke ground at NBS for the construction of one of the few cold neutron research facilities in the world. Speaking at the NBS research reactor site in Gaithersburg, Md., Brown said, "This country's ability to exploit a variety of emerging technologies will make or break us economically when the 21st century arrives. Results of cold neutron studies to be conducted at this facility can help the United States to turn the potential of these technologies into commercial successes. We need the very best facilities, like this one, if we are going to beat the competition to markets."

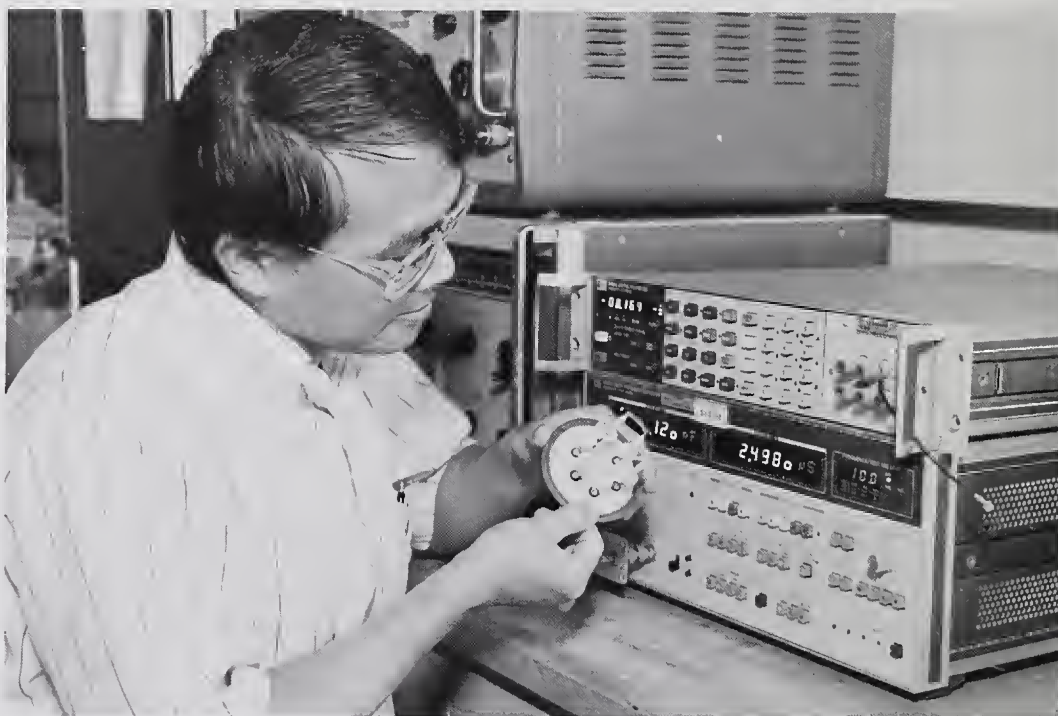
The new $25-million facility will make cold neutron research easily available to U.S. scientists working in such fields as materials science, chemistry, and biology.

Cold neutrons are low-temperature, hence, low-energy, neutrons produced by specially designed nuclear reactors. Cold neutron sources have become one of the most desired tools of modern materials research because they allow researchers to conduct experiments that would be impractical or even impossible with more energetic neutron sources.

The first experimental stations at the cold neutron facility are expected to be available late in 1989.

AT&T, DEC, AND NBS DEVELOP TEST METHODS FOR POSIX

Researchers from AT&T and Digital Equipment Corporation (DEC) are working with NBS to develop test methods for the Standard for Portable Operating System Environments, commonly known as "POSIX" (a trademark of the Institute of Electrical and Electronics Engineers [IEEE]). Test methods are needed by manufacturers and users to ensure that the operating system environments being developed conform to the proposed POSIX standard. POSIX was developed by IEEE with participation from industry and NBS. In addition, NBS is developing a Federal Information Processing Standard (FIPS) based on POSIX. FIPS are developed by NBS for use by the federal government.



NBS researcher Peter Huang examines his patented humidity-sensing device, which effectively senses relative humidity from zero to 100 percent with better accuracy than existing instruments.

NOVEL HUMIDITY-SENSING DEVICE DESIGNED

An NBS scientist has received a patent for the design of a device that uses organic polymers to sense and measure humidity. Peter H. Huang has been granted patent number 4,681,855 for the invention, which is an improvement over existing devices because of its expected long life, lasting accuracy, and ability to be used at high temperatures and humidities. Huang envisions many potential applications, especially in controlling the drying processes that support industries such as textiles, paper, chemicals, and food. Meteorological and electronics applications also are feasible.

A major weakness in existing commercial devices is hysteresis, or the inability of an instrument to measure abrupt humidity changes and then return accurately to the original value. Huang's system significantly reduces this problem while increasing sensitivity. For information, write or call Peter H. Huang, B312 Physics Building, NBS, Gaithersburg, MD 20899, 301/975-2621.

WEAR TEST APPARATUS FOR CERAMICS

Existing test methods to measure the friction and wear of metals are not designed to study the performance of advanced ceramics used in heat engines and other high-temperature environments because the material properties of ceramics are significantly different from steel. At high temperatures, the low thermal conductivity and diffusivity of ceramic materials can generate large temperature gradients in conventional test devices that obscure information on the friction and wear of advanced ceramics.

NBS has developed a new high-temperature, controlled-atmosphere ceramic wear test facility that features control of temperature to 1500 °C. The facility also permits researchers to study various gaseous environments as well as the chemical vapor deposition of high-temperature lubricants. For information on the new ceramic wear test facility, which is available for cooperative programs with industry, government, and universities, contact: Said Jahanmir, A215 Metrology Building, NBS, Gaithersburg, MD 20899, 301/975-3671.

IMPROVEMENT IN SUPERCONDUCTOR CONTACT RESISTANCE

As *NBS Research Reports* was going to press, NBS and Westinghouse researchers reported that they had lowered high-temperature superconductor contact resistance to a million times less than indium-solder contacts. This is a 100- to a 1,000-fold improvement over their previous results which are reported on page 12. The newest results are obtained by annealing the sputter-deposited silver contact pads on the superconductor in oxygen at temperatures up to 500 °C for an hour. (The previously reported technique involved temperatures up to 150 °C, but no oxygen annealing.) Where the intermediate (500 °C) temperatures can be tolerated, the annealing technique yields resistivities of about 10^{-8} ohm-cm^2 at 76 K for bulk sintered samples of $YBa_2Cu_3O_7$. This resistivity was measured for current densities of up to 100 A/cm^2. The voltage-current characteristic was nonlinear, having the character of a superconducting proximity effect; at lower current densities, below 30 A/cm^2, the resistivity was unmeasurably low. These results were presented at the Materials Research Society meeting in Boston, Mass., November 30-December 4, 1987. (Similar results were observed by a group led by Y. Tzeng at Auburn University using evaporative deposition and annealing for 5 hours at 500 °C.) For details, write or call Jack Ekin, Div. 724.05, NBS, Boulder, CO 80303, 303/497-5448.

REDESIGNED CIGARETTES COULD BE MORE FIRE-SAFE

After testing thousands of commercial and experimental cigarettes, NBS researchers have identified changes in the features of cigarettes that could reduce the lives and property lost each year in cigarette-related fires. Cigarette ignition of soft furnishings, such as upholstered furniture or mattresses, is by far the leading cause of fire deaths and injuries in the United States. The NBS researchers found that thinner cigarettes with less tobacco and less porous paper can significantly reduce the chance of igniting soft furnishings. They also found that cigarettes with filter tips were somewhat less likely to ignite furnishings. The type of tobacco made little difference. Another finding is that low-ignition tendency does not necessarily lead to higher tar, nicotine, and carbon monoxide yields as had been thought.

The researchers did not investigate the toxicity of the cigarette smoke or consumer acceptance. NBS economists analyzed the potential economic impacts of developing low-ignition cigarettes. They looked at the effects of five hypothetical modifications which might change the ignition tendency of cigarettes, including decreased circumference, tobacco density, paper porosity, and chemical additives.

COMPLETION OF FIRST PART OF DCA GATEWAY PROJECT

NBS researchers have completed the first part of a project sponsored by the U.S. Defense Communications Agency (DCA) to build gateways between Defense Department communication protocols and Open Systems Interconnections (OSI) networking protocols. OSI standards make it possible for different manufacturers' equipment and systems to communicate with each other through networks. The gateways will be used to maintain the agency's operations during conversion to OSI networks. Working with a guest scientist from IBM, the NBS researchers developed gateways and a test system for linking the Defense electronic mail protocol (Simple Mail Transfer Protocol) to its OSI counterpart (Message Handling Facility/X.400). The automated test system is used to determine whether products comply with the gateway specifications. Specifications are still being developed for a second gateway to connect the military's File Transfer Protocol and OSI's File Transfer, Access, and Management Protocol. When completed, these specifications and testing procedures will be available to computer and communications vendors as well as to test service organizations for use in developing gateway products that link Defense and OSI protocols.

NEW METHOD FOR PREDICTING THE HAZARDS OF FIRE

NBS researchers are issuing for trial use a unique, computerized method of predicting the hazards of fire. Known as HAZARD I, this prototype system for the first time takes into account the complex combination of physics, chemistry, fluid mechanics, heat transfer, biology, toxicology, and human behavior that influences the outcome of a residential fire.

HAZARD I will be distributed to a limited number of fire and building professionals who agree to evaluate it and provide comments to assist in the development of future improved versions of the method. Tools like HAZARD I are designed to complement existing codes and standards by enabling new materials and technology to be evaluated safely and quickly.

LAB ACCREDITATION PROGRAM FOR ASBESTOS IN SCHOOLS

A laboratory accreditation program for organizations that perform tests of asbestos in schools has been established by NBS under the National Voluntary Laboratory Accreditation Program (NVLAP) to meet the requirements of the Asbestos Hazard Emergency Response Act of 1986. This law requires the Environmental Protection Agency (EPA) to develop a program for the inspection, management, and abatement of asbestos in the nation's schools.

Under the law, NBS will accredit laboratories to perform analysis for asbestos content in samples of bulk insulation and building materials, and to analyze airborne particulates collected during school inspections and asbestos abatement projects. For information on the new asbestos program, contact Harvey W. Berger, A531 Administration Building, NBS, Gaithersburg, MD 20899, 301/975-4016.

AT&T SCIENTIST TO STUDY THIN-FILM POLYMERS AT NBS

AT&T Bell Laboratories is sponsoring a researcher under the Bureau's Research Associate Program to study the behavior of polyimide polymers at NBS. The research will be done using the NBS spectrofluorimeter to make fluorescence measurements on the structural properties of thin-film materials. Polyimides are important materials for use in electronics and other high-technology applications because of their thermal stability and suitability for photoresists.

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

CONSORTIUM TO INVESTIGATE EMI PROTECTION

NBS and the Building Industry Consulting Service International have created a consortium of organizations interested in curbing the potentially damaging effects of conducted electromagnetic interference (EMI). These rapid surges, caused by sources such as lightning, transformer cycling, and relay switching, can severely damage computers and other equipment. The consortium is concentrating on improvements in the performance and cost-effectiveness of surge protection devices and is emphasizing factors such as long-term stability and realistic voltage rating selection of these devices. The group also is measuring the propagation of EMI surges in the wiring systems of actual buildings to complement or confirm NBS EMI experiments under controlled laboratory conditions. Consortium members are at an advantage because they will have up-to-date information on the research as it develops, and participating organizations are providing direction on the scope of the project. Currently, eight organizations are taking part in the consortium. Others are welcome to join and can get more information by contacting Francois D. Martzloff, B162 Metrology Building, NBS, Gaithersburg, MD 20899, 301/975-2409. (NBS laboratories in Boulder, Colo., are concurrently researching "radiated" EMI, which is prompted by sources like walkie-talkies, citizens band radios, and radar.)

INDUSTRY AND NBS IN ADVANCED CERAMICS EFFORT

NBS has agreed to cooperate with the Ceramics Advanced Manufacturing Development and Engineering Center, Inc. (CAMDEC) to develop measurement technology, systems, and procedures for the processing of advanced ceramics. The establishment of CAMDEC, a not-for-profit Tennessee corporation, is the outgrowth of recommendations made by advanced ceramic leaders at a workshop held at NBS, July 10-11, 1985, on the "Future of the U.S. Advanced Ceramics Industry." CAMDEC has as its mission the creation of a national center for developing the processing and manufacturing technology required to commercialize advanced structural ceramics. Under the agreement, NBS will provide technical advice to CAMDEC, participate in non-proprietary research and development projects, and conduct cooperative tests at NBS and CAMDEC facilities. For information on the cooperative program, contact Stephen Hsu, A257 Materials Building, NBS, Gaithersburg, MD 20899, 301/975-6119.

PC VERSION OF NBS/EPA/MSDC MASS SPECTRAL DATABASE

A major international resource of more than 44,000 analytical mass spectra is now available for use on personal computers (PC's). The PC version was prepared from the NBS/EPA/MSDC Mass Spectral Database that is in use worldwide in a computer-magnetic tape format and as a six-volume, 7,000-page reference. The collection of evaluated electron ionization mass spectra of organic and inorganic substances was originally put together by the Environmental Protection Agency (EPA) and the National Institutes of Health. It is now maintained by NBS, EPA, and the Mass Spectrometry Data Centre (MSDC) in the United Kingdom. The PC database is contained on 13 high-density floppy disks that can be stored on a hard disk of any AT-class or XT-class PC. Rapid searches can be made for the spectra of specific chemical name, formula, molecular weight, or Chemical Abstracts Registry Number, as well as for spectra with pre-selected characteristics such as peaks at certain masses. The PC version of the NBS/EPA/MSDC Mass Spectral Database is available for $750. For information, or to obtain a license agreement, contact: Office of Standard Reference Data, A320 Physics Building, NBS, Gaithersburg, MD 20899, 301/975-2208.

ELECTROMAGNETICS LAB ACCREDITATION PROGRAM EXPANDED

The electromagnetics laboratory accreditation program, managed by NBS under the National Voluntary Laboratory Accreditation Program (NVLAP), has been expanded to meet requests from participating laboratories, manufacturers, and the U.S. Naval Air Systems Command. Test methods have been added to help laboratories improve the quality of their testing services on products that must meet Federal Communications Commission (FCC) approval and to assure the quality and performance of electronic devices used in military weapons systems.

The expanded program includes test methods for radio frequency devices such as receivers (FCC Part 15); industrial, scientific, and medical devices (FCC Part 18); radio transmitters (FCC Part 90); and a military standard (MIL STD 462) to measure electromagnetic interference characteristics. The electromagnetics program was initially limited to test methods for computing devices (FCC Part 15J) and for telephone equipment compatibility (FCC Part 68).

Laboratories interested in accreditation for any of the test methods offered under the expanded electromagnetics program, or for information on NVLAP, should contact: Harvey W. Berger, A531 Administration Building, NBS, Gaithersburg, MD 20899, 301/975-4016. ■

Back to the Basics

The needs of modern science and industry drive the basic standards research at the National Bureau of Standards to extremes: extremes of temperature, size, pressure, and above all, accuracy.

Thermometers have more uses in hospitals than simply checking patients' fevers. Roughly half of all clinical laboratory tests are sensitive to temperature—in some cases requiring accuracies of five-hundredths of a degree in temperature measurement.

Makers of refrigerators, integrated circuits, and nuclear waste casks all share a common concern. They don't want their products to leak.

Some of the most important advances in early clock design were developed to meet the needs of sailors—celestial navigation depends on time. Today, the needs of ships at sea still drive the time business, but they've gotten more demanding. With sophisticated electronic navigation systems an error of about three-thousandths of a second could put a ship (or plane) a kilometer off course.

All of these users of measurements and millions more throughout American industry and commerce owe something to the basic standards research done at the National Bureau of Standards.

It is here, for example, that the U.S. standard for mass, a small cylinder of platinum-iridium alloy, is kept in a safe in a temperature-controlled room.

Here, too, are the researchers, laboratories, and equipment behind national and international measurements of time, temperature, pressure, length, and the basic units of electricity.

Maintaining measurement standards, however, is only a part of the basic standards activities at NBS. The goal of Bureau researchers working in this area is to push against the current limits of physical measurement, to provide the underpinnings of theory and experiment for science and industry which demand ever-better levels of accuracy and precision.

The goal of Bureau researchers...is to push against the current limits of physical measurement, to provide the underpinnings of theory and experiment for science and industry....

For example. . .

NBS physicist James Schooley prepares to place a gauge block to preset the manometer system of the NBS gas thermometer, the most accurate instrument of its type in the world.

In the Dungeon

"We call this 'the dungeon'," James Schooley explains, somewhat unnecessarily. He is hauling up on a heavy trap door set in the floor of a basement laboratory. A short steel ladder leads below to a small chamber crammed with air-conditioning equipment and another trap door, leading to a still-lower chamber.

Down here in a small insulated cubicle, two floors below ground level, is the heart of the NBS gas thermometer. An assemblage of pressure fittings, wires, pipes, and various nondescript mechanisms, the gas thermometer looks somehow anachronistic, and it is. It is the perfection of 19th century technology, but for its particular task, it probably has no equal anywhere in the world. The gas thermometer is the basis of the international temperature scale.

We use the concept of "temperature" every day, and in some fields—clinical chemistry, scientific research, and chemical process control, for example—accurate temperature measurement is vital. But just what is temperature?

For most people, temperature is a number produced by a thermometer. There are many different ways to make thermometers, so some system is needed to make them all consistent. As a matter of convenience, thermometers are calibrated against the so-called "International Practical Temperature Scale of 1968" (IPTS-68). IPTS-68 is basically a list of reproducible physical phenomena, and an agreed-on set of "temperatures" for each phenomenon:

- ☐ Boiling point of oxygen— -182.962 °C
- ☐ Boiling point of water— 100 °C
- ☐ Melting point of zinc— 419.58 °C
- ☐ Melting point of gold— 1064.43 °C

and so forth. The IPTS-68 provides "fixed points" to nail down the temperature scale and give the scientist something handy for calibrating thermometers.

Part of the Bureau's work is to provide scientists and engineers with convenient access to IPTS-68. A series of NBS Standard Reference Materials (SRM's) have been developed to put IPTS fixed points in convenient form. Other SRM's provide additional fixed points that have been certified by NBS in terms of the IPTS, such as the clinical temperature standards, gallium, rubidium, and succinonitrile, which were selected because they have melting points near important reference temperatures for clinical chemistry tests.

IPTS-68 is only a convenience, however. "True" temperature is a phenomenon of thermodynamics, and it is best defined by the gas law, which says that for a given amount of a gas, the pressure and volume of the gas are directly related to its temperature. In principle, that sounds simple enough; in practice, the accurate measurement of "thermodynamic temperature" is such a finicky, painstaking business that it is only occasionally attempted.

"Temperature measurements can be made very poorly unless you are careful," explains Schooley. "We now know that IPTS-68 has an error of a half a degree (Celsius) in some ranges. The gas thermometer is still the best way to measure thermodynamic temperature, but it's very difficult to use. We worked extremely hard to get the melting point of aluminum to within 10 millidegrees."

Schooley is wrapping up an NBS effort to re-evaluate the practical temperature scale in terms of thermodynamic temperature that began almost 30 years ago when his predecessor, Leslie Guildner, began work on an improved, high-temperature gas thermometer. That instrument, cossetted and corrected for every conceivable source of error, has pushed the technology of gas thermometry about as far as it can go. It is probably the last of its kind in the world, according to NBS officials, because other national laboratories have dropped their efforts in anticipation of the NBS results.

The NBS data...will become a major factor in the planned 1990 revision of the International Practical Temperature Scale.

Guildner and his colleague Robert Edsinger helped establish, for instance, that the assignment of 273.15 kelvins to the ice-point of water (IPTS-68) was in error. It should be 273.22.

Who needs such accuracy? "For one example," says Schooley, "the physicists and chemists who measure properties of materials such as thermal expansion or heat capacity. Someone doing precise calorimetry finds it very sensitive to imperfections in the temperature scale."

The NBS data, which should be ready soon, will become a major factor in the planned 1990 revision of the International Practical Temperature Scale.

Standard Leaks...

have nothing to do with the evening news. The rate at which a gas leaks from one volume to another has become a matter of much industrial interest in the last couple of decades.

"There is a wide variety of products in our society whose performance or lifetime depends on their ability to retain or exclude gas," explains Charles Tilford, who oversees leak and vacuum standards. "Refrigerators, which have to retain coolants, integrated circuits—they're sensitive to moisture, vacuum systems of all kinds, automobile shock absorbers, nuclear weapons, and the casks used to ship nuclear wastes, these are all tested on a routine basis for leaks.

"Even soup cans. You can estimate the leak rate in food cans equivalent to the minimum size hole a microorganism can get through."

Measuring a leak may not sound too difficult, but these are very slow leaks. A typical industrial range, says Tilford, may be about from 10^{-9} to 10^{-13} moles (a measure of the number of molecules) per second. In more familiar terms, if you had a 1-liter container with an absolute vacuum, at those rates you could fill it to atmospheric pressure in (approximately) 1 to 10,000 years.

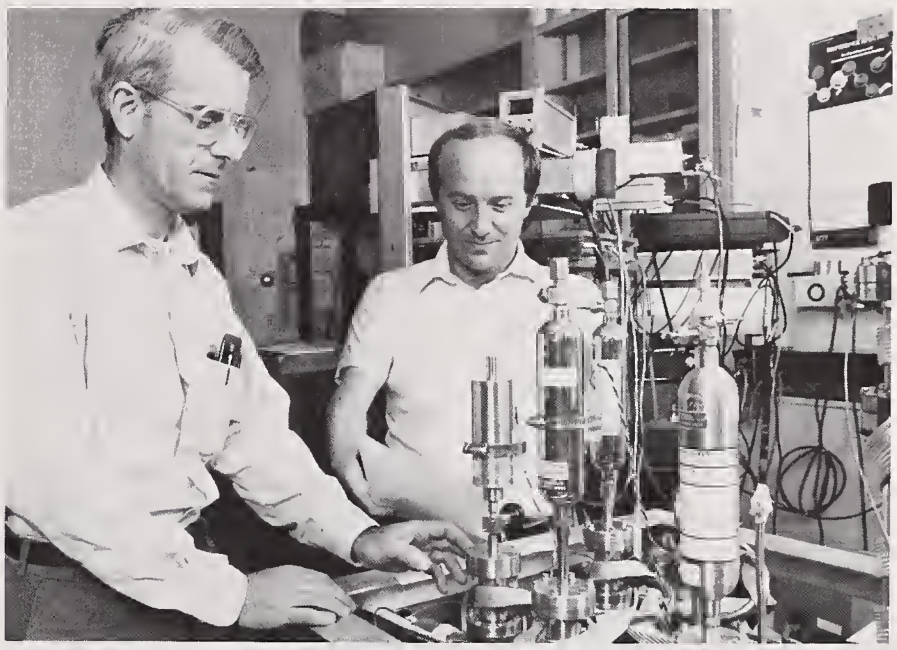
The most common way to measure such leaks is to put helium gas on one side of the vessel and a mass spectrometer tuned to helium on the other side. If any helium leaks through, the mass spectrometer detects it.

The problem comes in trying to calibrate such a system. "You use a 'standard' leak," says Tilford, "which is typically a glass thimble surrounded by a reservoir of helium which diffuses through the glass at a 'constant' rate. This gives you a known rate for calibrating your mass spectrometer."

In theory. In practice, helium-permeation leaks, although easy to make and use, are difficult to use accurately. For one thing, says Tilford, they are very sensitive to temperature. They are also difficult to calibrate. "Since we began our special test service for standard leaks," says Tilford, "we've had companies sending leaks for calibration that were leaking at about half their specified rate. We've heard stories that when you go to lower leak rates you can find errors of a factor of ten."

Leak-sensitive products are tested for maximum acceptable leak rates, so a 50-percent error in your standard translates to real money. Fifty percent low and you are rejecting or reworking units that are actually acceptable; 50 percent high and you are shipping units that can come back and haunt you with warranty repairs or product liability claims.

Until a year ago, the problem was exacerbated by the fact that the United States had no national standards for leak rate. Tilford and his colleagues Charles Ehrlich and Richard Hyland devised a calibration system based on the high-vacuum standards maintained by NBS. With support from Sandia National Laboratories, a nuclear research facility with an active interest in leak standards, they have developed a calibration service for standard leaks and have launched the first of a projected series of workshops in the use of leak standards.



NBS physicists Richard Hyland (left) and Charles Ehrlich discuss a typical "reference leak" to be calculated on the NBS primary leak standard.

"Right now we're working in what we think is the most widely used range, and with the most widely used type of leaks," says Tilford, "We want to broaden that range in both directions, faster and slower leaks."

"It's been a process of developing primary standards, understanding how the transfer standards—the helium-glass permeation leaks—behave, and making the calibrations useful to people through mechanisms like workshops. We also need to understand how people operate standard leaks. We've done a lot of work on this because operating procedures can have even more of an effect on your final measurements than the calibration of your standard."

The Smallest "Yardstick"

Some NBS researchers ask questions of less immediacy. Questions that arise from basic physics or that may affect the measurement systems of tomorrow.

How do you measure the almost unimaginably small? Where do you find a ruler that will mark off the distance between atoms?

For almost two decades, a handful of Bureau researchers have been refining the answer to those questions. Their tools are x rays, lasers, nuclear reactors, and small, perfect blocks of silicon crystal.

In an intricate experiment, x rays are passed through an "interferometer" carved out of a single block of silicon, and the shifting peaks of intensity as the crystal is moved, measured by a visible or optical laser interferometer, mark out the distance between adjacent planes of atoms in the silicon.

The distances involved beggar the imagination. Two planes of atoms in a near-perfect silicon crystal are separated by about 1.9 angstroms: about 0.000 000 007 5 of an inch. What's more, the experimenters estimate their accuracy at about 1 part in 10,000,000.

The work involved is so hair-raisingly delicate—even the fact that the solid crystal will expand ever so slightly when moved from room pressure to a vacuum chamber for measurement is a source of error—that you can count the number of labs in this business, worldwide, on one hand.

Why? "The motivation is to find a way to get from measurements in the optical wavelength region which form the international standard for length measurement to the scale of x rays and gamma rays," says Ernest Kessler, Jr. Division chief Richard Deslattes, Albert Henins, Geoffrey Greene, and Kessler make up the silicon-crystal lattice-spacing team.

Their closest competitor and collaborator is the Physikalisch-Technische Bundesanhalt (PTB) in West Germany. NBS and PTB have interchanged silicon samples and measured the difference between the two samples.

NBS physicist Albert Henins holds carefully cut silicon crystals used to precisely measure silicon-crystal lattice spacings.

When all the measurements are complete, the silicon block becomes an atomic-scale ruler, the spacing of its atomic planes known precisely. It can then be used in other experiments: to make direct measurements of the wavelength of x or gamma rays, for example. The gamma ray measurements are done at the special reactor facility of the Institut-Laue Langevin in France (ILL).

The NBS group ran into a stumbling block several years ago when unexpected instrument errors were discovered which badly flawed the first series of silicon crystal measurements: By "badly" we mean about 2 parts in 1 million—still quite outstanding by anyone's standard. Since then the apparatus has been completely redesigned and reassembled, and a new set of values, due to be published within the year, will report silicon-crystal lattice spacings at unmatched levels of accuracy.

The goals are scientific. Measured silicon crystals are the measurement link to the scale of gamma-ray wavelengths, important values for both theoretical and experimental physicists. Ultimately, this work provides a link between the standards for length and mass, according to Kessler.

"When you go high enough in gamma-ray energy, you can make accurate equivalent mass and energy measurements," he says. "At about 5 million electron volts, in principle, you can unify the scales of mass and wavelength at the 1 part in 1 million level. In fact, the current best known value for the mass of the neutron comes out of our work at ILL."

Work by the Bureau's time and frequency group made it possible, 4 years ago, to link the scales for time and length. At the frontiers of basic standards, the units of measurement seem to converge.

Pushing the State of the Art

This article only touches upon a small fraction of the basic standards research under way at the National Bureau of Standards. Nothing has been said about the work which ensures that all U.S. electrical measurements are referenced to NBS standards. Or the fact that the Bureau's work in pressure and vacuum standards is used in such critical areas as assuring the accuracy of airplane altimeters.

Or that time is kept for the United States by an NBS clock, and Bureau researchers in the NBS Boulder, Colo., laboratories are at work on ever-better systems not only for keeping time, but for passing it on to others. NBS researchers in Colorado at the Joint Institute for Laboratory Astrophysics contribute to fields as fundamental as gravity research and as practical as streetlight design.

"It is important to pay proper attention to basic measurements," observes Helmut Hellwig, acting director of the NBS National Measurement Laboratory. "Measurement plays an increasingly important role in all our industrial and commercial activities; it is particularly important to the quality of products and services offered by our high-technology industries.

"Much of our scientific, technological, and industrial development over the last few decades has been driven by measurement. Better, more accurate, state-of-the-art measurements have driven both practical and theoretical physics, chemistry, and industry, and have resulted in new knowledge, and ultimately, new and improved products and processes."

by Michael A. Baum
NBS Public Affairs Specialist

Will the Japanese Beat the United States in Superconductivity?

Adapted from remarks of NBS Director Ernest Ambler at the conference "Assessing the Commercial Realities of New High Temperature Superconductors," November 16, 1987, San Francisco, Calif.

I find it both fascinating and revealing that as soon as the first reports of laboratory successes with higher temperature superconductivity were announced, the news media began zeroing in on the question of whether or not the Japanese or others will beat us to the punch in capitalizing on this astonishing scientific advance. That is both good news and bad news.

For the first time, we are paying close attention to what the competition is planning when it comes to exploiting new research results: That is good news.

On the other hand an excessive amount of attention paid to how the Japanese are doing in superconductivity can distract us from solving our own problems, which have implications far beyond superconductivity: That is bad news.

"Will the Japanese beat the United States in superconductivity?" Actually, I think we may be asking ourselves the wrong question, or too narrow a question. The more important question is whether or not the Japanese or others will beat us in exploiting a whole range of new and emerging technologies. Although the commercial potential of these technologies is mostly in the future, many are closer at hand and better commercial bets right now than superconductivity.

Let me assert that the Japanese are attempting to dominate world markets in all of them. Among these technologies are:

□ Photonics, which includes applications of optical fibers, optoelectronics, and solid-state lasers to communications, computers, and information technology;

□ Advanced materials, including biomaterials, ceramics, composites, and now, superconducting materials; and

□ Automated manufacturing, especially the higher-level applications of robots, flexible manufacturing systems, and the broader scheme of computer-integrated manufacturing.

The United States is not unaware of the Japanese intentions and has been completely familiar with their very successful strategies and tactics for many years. So why are we so slow in revitalizing our own strategies? What is standing in the way of U.S. success?

Economic Barriers

Earlier this year, I headed up a Commerce Department group which examined the economic potential of important emerging technologies. It soon became clear to us that, while there should be no complacency, scientific research, technical ideas, and inventiveness are not our major problems when it comes to competing.

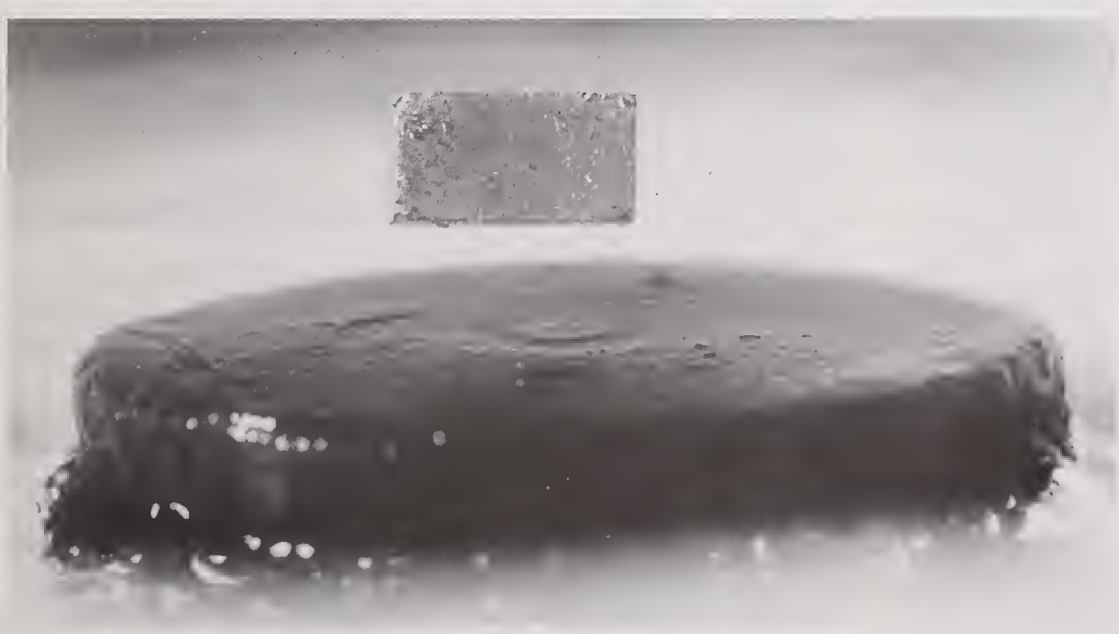
The most serious problems facing the United States are largely non-technical barriers. There are the so-called "macroeconomic" barriers, which are related to high costs of capital funds, antitrust regulations, and so forth.

The more important question is whether or not the Japanese or others will beat us in exploiting a whole range of new and emerging technologies.

But I think some "microeconomic" barriers are equally important when it comes to emerging technologies. These microeconomic barriers are structural and behavioral problems, and therefore, they are potentially the most intractable.

If you want to worry about U.S. competitiveness in superconductivity-based products, or any other high-technology products for that matter, in my opinion these are the things you should really be having nightmares about.

Here, we are talking about inade-



Recent advances in high-temperature superconductors have sparked an international race to produce the first product using these new materials.

quate long-range strategic planning by U.S. firms and/or a failure to execute long-range strategic plans in the face of short-term and unexpected difficulties. This is often because of excessive importance attached to short-range financial statements and concomitant managerial incentives.

The fact of the matter is that in the United States, as compared to Japan, our corporate leaders are judged and rewarded for short-term performance. They are not rewarded for the long haul. Recent activities in mergers, leveraged buy-outs, and hostile takeovers make these pressures even stronger, and their implications for long-range R&D investments are ominous.

Product vs. Process Technology

We also have to face up to other problems relating to corporate strategies. We have a poor mix of engineering improvements in this country, with too much focus on product technology and not enough attention on process technology. This makes it difficult for companies to adapt to rapid advances in technology because they may become too locked into a particular product.

The Japanese have shown us the value of taking the larger view. They focus not just on the better product, but on a better way to make the product so that quality and reliability can be built into the product and so that technological changes can be readily incorporated to gain maximum performance at minimum cost.

Integration and Cooperation

This points to a broader, more basic problem that has plagued U.S. industry: We have not been properly integrating research, development, manufacturing, and marketing functions.

It is vital to have effective communication among these functions within the corporate environment in order to move new technologies rapidly to the marketplace. The length of time from research to marketing—the technological life cycle—has been compressed substantially, and the Japanese have shown that they understand that also.

Better integration of these functions is probably one of the best ways to achieve greater productivity in our high-technology manufacturing enterprises.

We have not been properly integrating research, development, manufacturing, and marketing functions.

These microeconomic barriers are people-oriented and managerial in nature, and, therefore, they fall squarely on the backs of the private sector. But we all must help.

I have mentioned the need for greater cooperation among corporate R&D, manufacturing, and marketing functions. Likewise, the lack of cooperation and integration among institutions is formidable.

That is due in part, I think, to the fact that all of us, but especially corporate managers, are trained to compete rather than to cooperate.

We are fighting in global markets where the scale of efforts demand we use all available resources. We are seeing some major improvements in this regard, with the formation of dozens of research consortia and changes in the ways in which federal laboratories, for instance, can work directly with companies and grant very favorable patent rights.

I have given much attention to these barriers to emerging technologies because I am convinced that they must be recognized and addressed both bluntly and quickly if the United States is to be commercially competitive when the next century dawns.

Superconductivity Competition

Now, where are we specifically in terms of commercializing high-temperature superconductivity?

My own opinion is that some of the structural and behavioral barriers have been addressed somewhat better in superconductivity than in other emerging or soon-to-emerge technologies.

For one thing, there is a sense of urgency for a change, which is promising. We certainly can't be accused as a nation of being complacent about the Japanese challenge in this field.

We have seen a dramatic buildup in research capabilities. Japan is not alone in assembling corporate research efforts of 50 or more people to work on this exploding field, and cooperation between institutions is pretty good. The United States is probably about on a par with the Japanese at this point.

The obvious gap today is that everyone—Americans and Japanese alike—lacks the necessary theoretical understanding of high-temperature superconductivity. The result is that current research on both sides is somewhat empirical.

Making products is a private sector job. There is no substitute for action by industry.

If, in fact, a U.S. strength over the past several decades has been our broad and deep basic science

(Official White House Photograph—Bill Fitz-Patrick, Photographer)

At a federally sponsored conference, President Reagan announced an 11-point initiative to ensure U.S. readiness in commercializing superconductivity advances. Here Reagan discusses high-temperature superconductors with NBS scientist Stephen Freiman amd Secretary of State Shultz.

capability, we can be optimistic about the odds that we will advance the basic theory of superconductivity faster than the Japanese, or the Europeans, for that matter.

But we have learned the hard way that leads in basic knowledge are all too fleeting, and we can't be complacent. That's especially important considering the substantial Japanese efforts in electronics and advanced ceramics that position them so well for possible high-temperature superconducting applications.

So what do we have to do?

☐ We need to focus on achieving comparative advantages in applied R&D, for both product and process development. This includes designing in quality and manufacturability during applied R&D.

☐ We need to work on process control and quality assurance techniques. This would have been especially true in the ceramics area even without the discovery of high-temperature superconductors.

☐ We need to adopt longer range marketing strategies which emphasize global market share over short-term profits.

☐ We need to better integrate the research, development, manufacturing, and marketing strategies for superconducting products.

☐ We need to compress the length of time between product concept and marketing.

☐ We need to think broadly about targeting entire systems that will utilize high-temperature superconductivity principles. As with silicon, you won't make a lot of money on the raw materials—it's the integrated circuits that pay off.

Government Role

The federal government has an important part to play. Government can provide support, through R&D, through procurement especially in the defense area, through fair and decisive actions to provide a good business environment, to help industry turn the technological promise of superconductivity into commercial success.

But government has never been successful in showing industry how to do its job, and there is absolutely no reason to think that will change in the future, or that superconductivity is different in this regard from other areas of technology.

Making products is a private sector job. There is no substitute for action by industry. And I mean action on its own behalf and not just in response to government requirements.

So, where does that leave us?

Nothing is inevitable about the competition in superconductivity. No good reasons exist for us not to beat the Japanese and the Europeans in superconductivity.

But we must translate today's sense of urgency into actions. We must be willing to make fundamental changes in corporate and government strategies if we are to overcome the structural and behavioral barriers blocking the commercial prospects for this and other technologies. If we don't I think we will do well in the sprint to commercialize superconductivity and end up losing the longer race.

We must *learn from* rather than *repeat* the mistakes of the past if we are to make sure the first—but not *just* the first—high-temperature superconducting products carry a "Made in the USA" label.

Low-Resistance Contacts Developed for High-Temperature Superconductivity

High contact resistance has been a major obstacle to eventual commercial applications of the new high-critical-temperature ceramic superconductors. Work by Jack W. Ekin of the NBS Electromagnetic Technology Division, Boulder, Colo., and Armand J. Panson and Betty A. Blakenship of the Westinghouse Research and Development Center, Pittsburgh, Pa., has produced a new method for making low-resistance electrical contacts on these superconductors.

The new method, announced September 18, 1987, reduces the contact resistivity several thousand times below that previously achieved with conventional contacts.*

Resistance at electrical contacts causes heating in any device, but it is particularly fatal in superconductors. Even modest heating can raise the temperature of the superconductor enough to weaken or destroy the property of superconductivity.

The high resistance that usually occurs where external leads are attached to ceramic superconductors is an obstacle to both measurements and practical applications of the newly developed high-critical-temperature superconductors. Future superconducting magnet and circuit board applications will require resistivities of less than 10 to 100 micro-ohm-cm^2, but contact heating caused by high resistance presently limits measurements of critical current in bulk samples at low temperatures and low fields.

The new contacts have a surface resistance of about 10 micro-ohm-cm^2 at 76 kelvins (liquid nitrogen temperature), when tested on the new yttrium-barium-copper-oxide ($YBa_2Cu_3O_7$) superconductor. This resistance is 1,000 to 100,000 times lower than that exhibited by indium solder, silver paint, or silver epoxy contacts. The contact process is carried out at temperatures below 200 °C and therefore affords good control and avoids possible degradation of the underlying superconductor from excessive diffusion of the contact material which can occur at high temperatures. The method also allows post-firing shaping and processing steps before contacts are applied.

*As *NBS Research Reports* was going to press, the researchers announced further advances in this work. See page 3 for update.

Low-resistance contacts (white squares at ends of superconducting black bar) are being readied for low-temperature testing.

The researchers developed the new method after noticing a correlation between the ages of many superconductor samples and their contact resistivities. They reasoned that, if age were a factor, reducing the time the surface was exposed to air should improve the contacts. Further testing indicated that significant surface deterioration occurred in a matter of seconds.

The new method involves three steps, which work together to produce low contact resistivity. Minimizing the air exposure time minimizes the degradation of the superconductor surface that occurs before making the contacts. Sputter etching the surface removes the degraded layer, and depositing a thin layer of a noble metal—silver and gold were used—protects the surface and minimizes further degradation of the superconductor surface.

The exposure of the surface can be minimized, or preferably eliminated, by reducing the time between the final firing and the processing of the contact pad, and more importantly, by keeping the superconductor in an atmosphere devoid of moisture, carbon dioxide, and other gases that interact with it. Pure dry oxygen or inert gases such as argon may serve as protection. Variations of this general method, such as glow-discharge cleaning followed by evaporative deposition of the noble metal, may yield good results, too.

Other contact materials were tried, but silver proved much better than indium and somewhat better than pure gold. Moreover, silver does not degrade the bulk superconductor as much as copper does on reheating. The contacts showed consistently low resistivity and were stable when exposed to air for more than 4 months.

The new method... reduces the contact resistivity several thousand times below that previously achieved with conventional contacts.

Further details of the new method will be published in a forthcoming issue of *Applied Physics Letters.* Preprints may be obtained from Jack Ekin, Div. 724.05, NBS, Boulder, CO 80303; ask for the "Low Resistivity Contact" paper.

by Collier Smith
NBS Public Affairs Specialist

IGES: Translating Electronic Tongues

The proliferation of computer systems has the potential to erect a modern-day Tower of Babel, a confusion of electronic "tongues" that can add cost and complexity to most computer-aided tasks, from word processing to design and manufacturing.

But unlike the biblical tower that was toppled by a communications failure, today's predicament lends itself to solution. For users and manufacturers of computer-aided design and manufacturing (CAD/CAM) systems, the most widely accepted answer is the Initial Graphics Exchange Specification, better known as IGES. The specification provides a "neutral file" for storing the geometric information and drawings typical of the CAD/CAM systems used by parts manufacturers of all types and architectural and construction firms. The file serves as an intermediary, facilitating the transfer of data between incompatible systems.

IGES is the product of an NBS-guided voluntary organization that goes by the same acronym and currently has more than 600 members who represent some 250 companies and agencies. The 8-year-old cooperative effort, born out of industry-wide frustration over the communication impasse between computers, has been so successful that it has fostered an even more ambitious standardization scheme, the Product Data Exchange Specification (PDES). PDES, which probably won't be ready for commercial application until the early 1990's, will allow for swapping not only geometric data, but every single detail about a part—everything that a computer-operated machine will need to make the part.

If experience with IGES is any gauge, PDES will be well received. In 1981, less than 2 years after a national meeting of CAD/CAM users and vendors voiced the need for a "translation format," the first version of IGES was issued and adopted by the American National Standards Institute as a major portion of its standard for the "digital representation for communication of product definition data." The evolution from idea to usable specification proceeded at what can rightfully be described as a breakneck pace in the deliberative arena of industrial standards.

According to IGES chairman Bradford Smith, storing data in an almost universally accepted format—IGES—assures that digitized product models will always be available.

Widespread Use

The rapid turnaround and acceptance of IGES testify both to the need for the specification and to the value of a cooperative response to an industry-wide problem. Philip Kennicott of the General Electric Co., Walter Braithwaite of the Boeing Co., and Roger Nagel, formerly of NBS now with Lehigh University, are credited with leading and coordinating the effort. Several government agencies, including three branches of the military, were also heavily involved. In fact, the Air Force Computer-Integrated Manufacturing Program is a major sponsor of the IGES organization.

Today, virtually all U.S.-made CAD/CAM systems are compatible with IGES, a matter of adding a post-processor for converting data to the neutral format and a preprocessor for translating IGES data into the receiving system's native format. Among users, IGES, soon to be issued in its fourth version, has "worked its way into the nooks and crannies of many manufacturing businesses," says William Burkett, senior engineer at the McDonnell Aircraft Co. in St. Louis, Mo.

In effect, the specification is a "superset" of modeling entities that accommodates the large, yet highly specialized and highly secretive CAD/CAM field, says the Bureau's Bradford Smith, IGES chairman. "You cannot decree," he explains, "a particular brand of CAD/CAM system for all the units in your business enterprise because there is no one system that will solve all needs. Each CAD system has its own niche in the market—the stuff that it does really well. The trouble is the units have to do business with each other. I think the data exchange of product models will always be with us."

Among users, IGES...has "worked its way into the nooks and crannies of many manufacturing businesses."

An alternative to the neutral-file approach for exchanging models is to use direct converters, programs that translate data from one system into the format used by another. This alternative quickly becomes unwieldy and prohibitively expensive, as the number of converters required for data exchanges grows geometrically with the number of CAD/CAM systems. To link four systems, for example, eight direct converters are needed; introducing a fifth system requires eight additional converters. Four systems that exchange data through IGES also use eight translators—a preprocessor and post-processor on each machine. But for each subsequent addition to the CAD/CAM network, only two additional translators are needed.

According to Kennicott, an information scientist at GE's corporate research and development center in Schenectady, N.Y., heavy reliance on direct converters eventually imposes penalties. "It's not the expense as much as it is the delay," he says. "It can take 6 months to a year" to develop one converter. And because the typical CAD/CAM system is updated about twice a year, the task of keeping converters current may be constant.

"IGES," says Smith, "has been popular as a means of exchanging part models between CAD systems" within the same company and between those of different firms, such as contractors and subcontractors. Ultimately, the specification may prove even more valuable as a tool for archiving product models developed on outdated systems.

"The CAD market is very competitive and quite volatile," Smith explains. "What do you do if you have the system of a vendor who has gone out of business? It might be useful for a couple of years, but it will become obsolete relatively soon. You can't just throw out the old system and get a new one. What about the hundreds of thousands of staff hours of CAD terminal time that you've put in on that system? What about your entire corporate database of product data models that's on that system?"

Smith says that a growing number of companies will discover that IGES is the answer to this quandary. Storing data in an almost universally accepted format assures that digitized product models will always be accessible, regardless of the vagaries of the CAD/CAM market.

Keeping Pace

IGES, however, must be responsive to the almost continuous improvement of CAD/CAM technology, which explains why four versions of the specification have been developed since 1980 and why a fifth will be issued in the next year. While limited initially to handling geometric data in the wire-frame format typical of blueprints, each succeeding version of IGES extended capabilities for two- and three-dimensional representations of geometric entities, including surfaces; for finite-element modeling, which is necessary for design analysis; and for annotating dimensions, tolerances, and other product data. Although compatible with earlier versions, IGES 4.0 will offer constructive solid geometry, one of two popular methods for solids modeling. The next release will include the other method, known as boundary representation.

Before it is released, a new IGES version is subjected to painstaking review within the organization. Drafted and redrafted, each new feature, extension, and application are scrutinized, debated, and demonstrated by technical committees before the entire membership votes on their acceptance. "We have been very particular in what we do," Smith says, "and very responsible, I think." As a result, IGES "has a good following among vendors." In fact, two CAD/CAM vendors were so confident in the organization's work that they added the IGES solid geometry feature to their systems after it was approved in balloting, but well before it was officially released in the soon-to-be published fourth version.

...some of the harshest critics may reside within the organization itself, but their ideas and suggestions foster improvements that are incorporated into future IGES versions.

The Criticisms

IGES does have its detractors who complain that data exchanges take too long, the neutral file is too large, or transfers occasionally result in errors. Some of the criticisms are valid, Smith and other members of the IGES organization acknowledge. In fact, some of the harshest critics may reside within the organization itself, but their ideas and suggestions foster improvements that are incorporated into future IGES versions. In response to complaints that the neutral file consumes too much computer memory, for example, the third version includes an optional technique for reducing the file size by two-thirds.

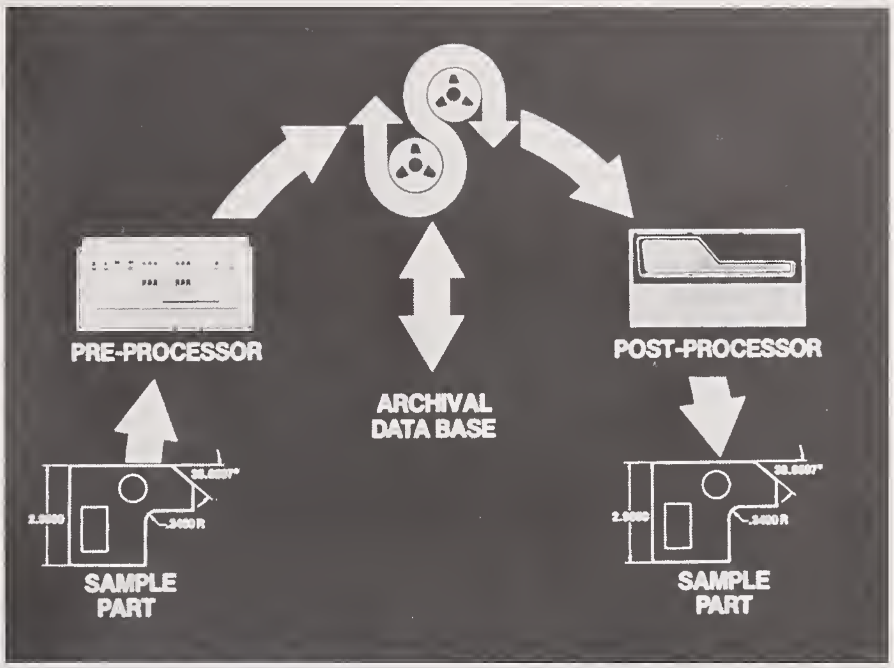
Data transfer from one CAD/CAM system to another "can take anywhere from seconds to hours, and it varies from computer to computer," Smith says. But even if it takes hours, an exchange through IGES is a much faster alternative "than sitting a CAD operator down and regenerating everything," he says.

While some transfers are flawless, others result in lost information, a problem, according to Smith, that usually does not originate with IGES. Two systems, for example, may not share a concept—say, a spline curve. If the target system is not programmed to handle a spline curve, it may choose to represent this geometrical information as a series of lines that approximate the curve, or it may jettison it altogether, leaving a blank spot on the screen.

"You have to recognize and work within certain constraints," explains Charles L. Stoddard, CAD/CAM requirements analyst at Pratt-Whitney in West Palm Beach, Fla. Stoddard says he routinely exchanges data between systems "that don't even think alike." These transfers, however, are more complicated, requiring foresight and close coordination.

"I spend a lot of time working with people in the exchange of data between systems," he says. "You still have to be able to communicate effectively. If you do that, then the data become usable." Stoddard admits to occasional frustrations with IGES, but he and his colleagues regularly use the tool. At Pratt-Whitney, which has several different CAD/CAM systems, IGES is used almost hourly for in-house transfers of data and for exchanges of parts models between facilities, Stoddard says.

Smith acknowledges that some exchanges are demanding in their rigor and that errors can arise. "But," he asks, "if you transfer 90 percent of the information, isn't it easier to regenerate the missing 10 percent than it is to regenerate the entire product model?"



An advantage of the IGES format is that users do not need special translators for each different piece of equipment used. Rather, they are only required to have a translator to and from the IGES format. These translators, called pre- and post-processors, are generally available from equipment vendors.

Sometimes errors originate in the software of the pre- and post-processors that the vendors have added to their systems. Simply put, the problem is that some vendors have been less than thorough in implementing the specification, despite their claims to the contrary. The IGES organization is developing a test for evaluating the completeness and accuracy of translators. The Society of Automotive Engineers plans to use the test in a voluntary validation program it will offer CAD/CAM vendors.

IGES users range from big firms, such as Pratt-Whitney, General Motors, Boeing, and McDonnell Aircraft, to small subcontracting "job" shops. The Department of Defense (DOD) also is a major proponent of IGES, and it is taking measures to assure greater use of the specification by contractors.

"DOD has gone on record that they want to procure all weapons data packages in digital form," Smith explains. "That includes all documents—text and illustrations, all drawings, and all three-dimensional product models. By 1990, they want to be doing business digitally." As a step in that direction, DOD will soon issue a specification (Military Standard 1840) requiring that IGES be used for technical illustrations, two-dimensional drawings, and printed circuit boards.

As envisioned, PDES will be used to produce a "computer-sensible description of products."

Standard for the Future

Meanwhile, the Product Data Exchange Specification is beginning to take shape. As envisioned, PDES will be used to produce a "computer-sensible description of products," explains Kennicott. To some extent, this can already be done with IGES, but the general consensus within the organization is that a much more comprehensive and exacting specification is needed, he says.

PDES will be a unifying thread in efforts to develop a truly computer-integrated manufacturing environment, linking "islands of automation" that now act independently rather than in concert. As McDonnell Aircraft's Burkett sees it, the specification could foster integration to the point that buying CAD/CAM systems and other automated equipment would be much like purchasing components for a stereo system—just as audiophiles assemble stereo systems with speakers, amplifiers, and other components from a variety of suppliers. Freed of compatibility constraints, manufacturers could focus on the price and performance of each equipment piece.

Obviously, PDES will not only be used to transfer graphic representations of parts, but also a wide range of non-geometric data, such as manufacturing features, tolerance specifications, properties of materials, and surface finish specifications. Smith says the specification will "support the entire product-design and -manufacturing life cycle. So, PDES will have data elements that far surpass those in IGES."

Experience with IGES is the springboard for PDES, but the new specification will be entirely different in its construction, guided by the database-design principles of computer science and by the tenets of information modeling. As a result, Smith says, PDES, despite its greater sophistication and complexity, should be "much simpler and easier to implement" than IGES.

The PDES effort also will borrow heavily from the U.S. Air Force's Product Definition Data Interface project, carried out by McDonnell Aircraft Co. Tailored primarily to the needs of the aircraft industry, the ongoing project has developed and demonstrated the hardware and software to transfer parts data all the way from the design and engineering phases to the applications programs of the manufacturing phase.

Development of PDES parallels the International Standards Organization's efforts to establish a worldwide Standard for the Exchange of Product Model Data (STEP). If all goes according to plan, the first version of PDES, which already is in review, will be presented in 1988 as the official U.S. proposal for the international standard.

Smith anticipates that the earliest users of PDES will be very sophisticated high-technology companies, those involved in extending the applications, for example, of robotics, computer-aided vision, and artificial intelligence. For other parts designers and manufacturers, IGES, which will continue to be refined and enhanced, will satisfy most needs for transferring data files. But as technology advances, Smith predicts, the ranks of PDES users will begin to swell.

...the specification [PDES] will "support the entire product-design and -manufacturing life cycle. So, PDES will have data elements that far surpass those in IGES."

by Mark Bello
Washington, D.C.-area Science Writer

Lifting System Failure Probable Cause of Fatal Building Collapse

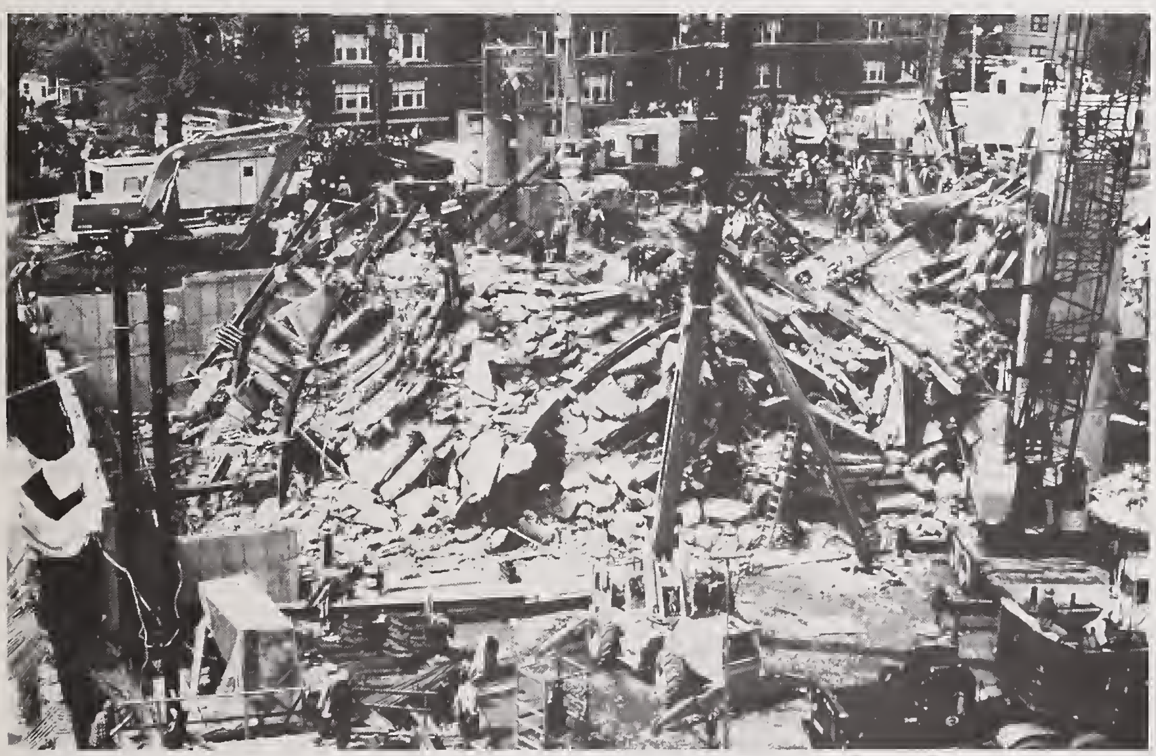
At approximately 1:30 p.m. on April 23, 1987, the L'Ambiance Plaza, an apartment building under construction in Bridgeport, Conn., collapsed, killing 28 construction workers. This was the largest loss of life in a U.S. construction accident since 51 workers were killed in the collapse of a reinforced concrete cooling tower under construction at Willow Island, W. Va., in 1978.

On April 24, the U.S. Occupational Safety and Health Administration (OSHA) asked the National Bureau of Standards to investigate and determine the most probable technical cause of the collapse. A team of engineers from the NBS Center for Building Technology arrived at the site of the collapse that same day to begin the investigation.

The building was being constructed using the lift-slab technique. The floor and roof slabs were cast one on top of the other on the ground. The slabs then were raised, most in packages of three, by a lifting assembly consisting of a hydraulic jack, threaded jack rods, and attachments.

At the time of the collapse, a package of three slabs for floors 9, 10, and 11 of the west tower was being put into place and temporary wedges were being installed under the 9th floor slab. The NBS investigators determined that the failure of a key component of the system for lifting concrete floor slabs was the most probable cause for the building's collapse.

Specifically, the collapse most probably began when a jack rod supporting three concrete floor slabs slipped out of a u-shaped opening in a steel bracket. The bracket, or lifting angle, was part of a steel collar, known as a shearhead. Shearheads were placed around individual steel columns on the two-tower complex. Concrete floor slabs were cast around the shearheads.



The failure of a key component of the system for lifting concrete floor slabs was the most probable cause of the L'Ambiance Plaza building collapse on April 23, 1987.

NBS researchers pinpointed the location where the jacking system used to lift the slabs into final position most likely failed. They concluded that the load placed on a jack at one of two columns caused parts of the shearhead on the 9th floor slab to deform, allowing a jack rod and nut to kick out from the shearhead. This caused the three floor slabs to fall, resulting in the collapse of the entire west tower and then the east tower. This failure mechanism was duplicated in NBS laboratory tests.

"Our investigation of this tragedy, as well as earlier failures, points out the need to pay more attention to the structural integrity of buildings during the construction process," said Charles Culver, chief of the Structures Division in the NBS Center for Building Technology.

Culver, who led the NBS investigation, said "Special care must be given so that structures can withstand the load experienced during construction, and so that the failure of a single component, like a lifting system, does not bring down the entire structure through a progressive collapse, as was the case with L'Ambiance Plaza."

The researchers investigated a variety of possible causes of failure, but concluded that only the lifting system failure played a significant role in initiating the collapse. The possible causes of the initial failure which were considered and ruled out included the quality of materials used in the structure, the use of a horizontal jack to plumb the structure, inadequate resistance to lateral movement due to the lack of guy wires and improper placement of supporting shear walls, earth pressure against a basement wall, and foundation settling.

NBS researchers arrived at and confirmed their conclusions with laboratory tests of the debris, computer analyses, on-site investigations, an extensive review of project documents, and interviews with eyewitnesses.

In addition to a series of computer analyses, laboratory tests were conducted to evaluate the properties of materials like the steel and concrete used in the construction. Compression tests were conducted on concrete cores. Tensile tests, metallographic and chemical analyses, hardness tests, and fracture analyses were conducted on the steel columns and welds. Tensile tests also were conducted on the post-tensioning tendons used to give the concrete slabs added strength.

Other tests were carried out on individual components and assemblies of the lifting system. Tensile tests were carried out on the jack rods and attachments. Load tests were conducted on the shearhead-column assembly and the lifting assembly (jack, jack rods and attachments, and shearhead) to see how they performed.

A team of NBS researchers was involved in the $375,000 investigation, some full-time, some as needed. The work was done primarily by seven researchers in the NBS Center for Building Technology, and was directed by Culver, a civil engineer. Researchers in two other areas of NBS, the Fracture and Deformation Division and the Inorganic Analytical Research Division, also assisted in the investigation.

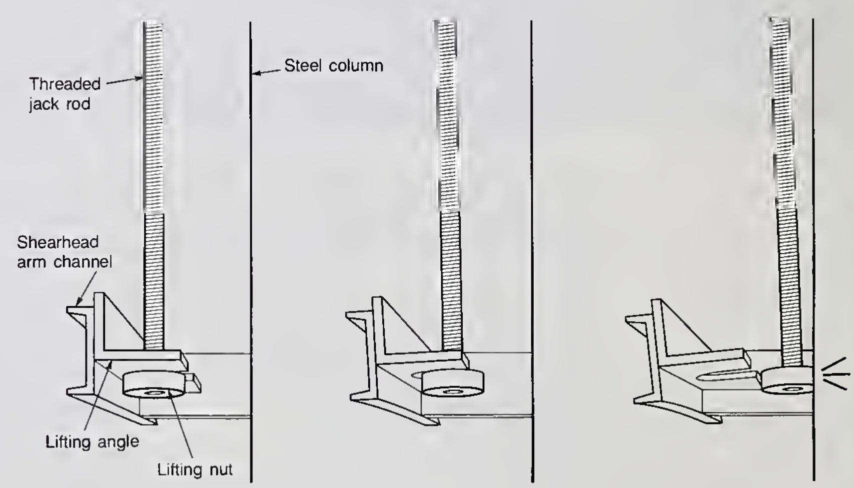
"Our investigation of this tragedy, as well as earlier failures, points out the need to pay more attention to the structural integrity of buildings during the construction process."

NBS, which has no regulatory authority, carried out the investigation for OSHA specifically to determine the cause of the collapse. The NBS researchers did not evaluate the overall design of the structure, nor was it NBS' role to assess responsibility for the collapse.

NBS investigation results are distributed widely to help designers, builders, and regulatory officials improve construction safety. The 314-page report, *Investigation of L'Ambiance Plaza Building Collapse in Bridgeport, Connecticut* (NBSIR 88-3640), that NBS prepared for OSHA is available from the National Technical Information Service, Springfield, VA 22161, for $30.95 prepaid. Order by title and PB #88-112438.

The NBS report on the investigation was released at an OSHA press briefing on October 22. A 22-minute videotape of Culver explaining the NBS findings can be purchased, in either Beta or VHS format, for $30 from the Public Information Division, A903 Administration Building, NBS, Gaithersburg, MD 20899, 301/975-2758. Make checks payable to the National Bureau of Standards; an information package is included.

by Jan Kosko
NBS Public Affairs Specialist



The L'Ambiance Plaza building collapse most probably began when a jack rod supporting three concrete floor slabs slipped out of a u-shaped opening in a steel bracket called a lifting angle (right). The lifting angle was part of a steel collar known as a shearhead (center). Shearheads were placed around individual steel columns and concrete floor slabs were cast around the shearheads. The drawing on the far right shows the complete lifting system.

NBS Structural Failure Investigations

As a federal science and engineering research laboratory, the National Bureau of Standards has a long history of investigating structural failures. The investigations focus on determining the most probable technical causes of the failure. Since NBS has no regulatory authority and does not promulgate building standards or codes, it is often viewed as a neutral "third party" which can conduct independent investigations. Through its Center for Building Technology, NBS develops the tools and technology to test and improve the performance of structures.

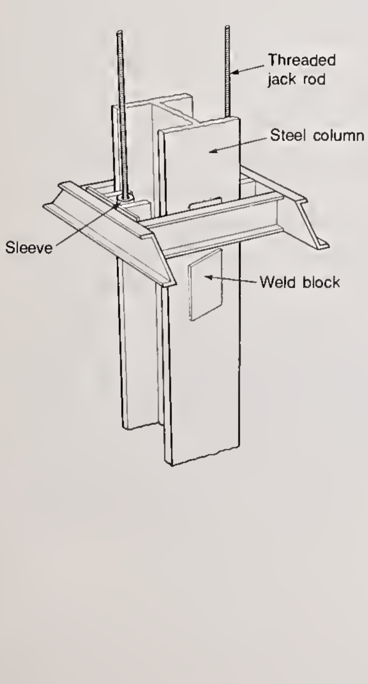
Typically, NBS researchers conduct an extensive field investigation at the site of the building failure to determine conditions before and after the failure. Documents such as drawings, specifications, and inspection reports are reviewed to gain information about the structure as it was designed. Extensive laboratory tests on materials are conducted to determine physical properties. NBS may fabricate mockups or replicas of parts of the structure and test these also. In addition to laboratory tests, NBS researchers can use computers to model a structure and analyze and predict its structural performance.

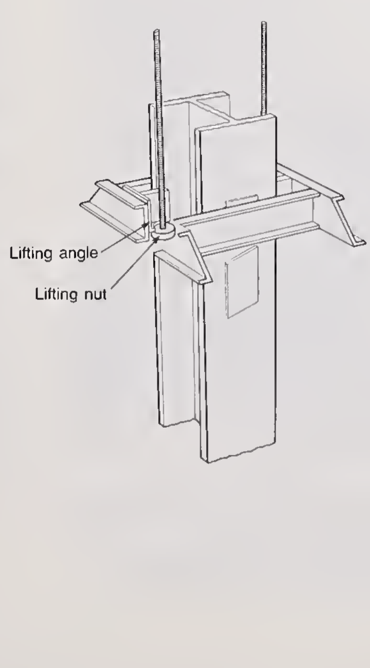
The NBS laboratories are extensively equipped; some of the facilities are one-of-a-kind. For example, NBS has several types of universal testing machines which can apply forces in several directions for structural components up to 60-feet tall. Other facilities include materials research laboratories for characterizing materials, and a high-performance computer graphics laboratory.

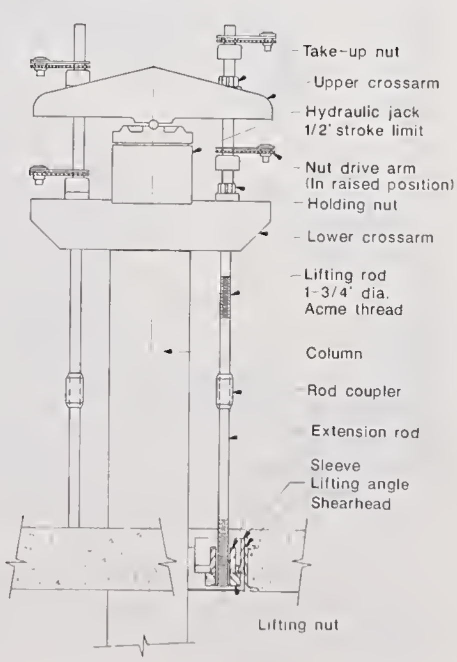
Requests for assistance in a structural investigation can come from other federal agencies, such as the Occupational Safety and Health Administration, state and local governments, or other organizations. Also, NBS may initiate an investigation of a significant failure after consulting with local authorities.

Investigations that NBS has conducted include the collapse of walkways in the Hyatt Regency hotel in Kansas City, Mo., and construction failure of a reinforced concrete cooling tower at Willow Island, W. Va. In addition, NBS investigated the structural soundness of the U.S. Embassy office building under construction in Moscow.

The results of these investigations are made public and help ensure that those involved in the building process understand the most probable causes of these accidents. Under a grant from NBS, The University of Maryland is developing a computerized database containing case histories of structural failures in the United States.







Six NBS Projects Win 1987 I-R 100 Awards

Innovations in semiconductors, sensors and measurement techniques for quality control, and chemistry were among the six projects from the National Bureau of Standards to be given I-R 100 awards this year.

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 17, 1987, in Chicago, bringing to 57 the number of I-R 100 awards NBS has received since first entering the competition in 1973.

Descriptions of the award-winning projects follow.

Crystal Axis Detection

Sidney Weiser. formerly of the NBS Center for Manufacturing Engineering, now retired, earned an I-R 100 award for the invention of an automated laser scanner that determines the orientation of the crystal axis in single-crystal semiconductor materials.

The proper alignment of crystal axes is an important element in the manufacture of semiconductor devices, which are fabricated on thin "wafers" sliced from a single crystal of silicon or other material. Weiser's crystal axis laser scanner was developed for a particularly difficult case: the crystals of cadmium telluride which are the heart of mercad telluride infrared detectors.

Previous methods of determining the major axis of cadmium telluride crystals required the use of x-ray diffraction techniques, which work only on wafers and require from 5 to 20 minutes per observation. A more recent technique depends on the reflection of laser light from the crystal surface which has been selectively etched to highlight the crystal planes. Very low signal-to-noise ratios make this technique difficult to use.

Weiser's instrument uses a significant modification of the laser scattering approach and a computerized pattern recognition algorithm to make the same measurement in less than a second—so fast that the machine can easily prepare maps of multi-crystalline areas. The instrument works with both single wafers and the original crystal boule from which the wafers are cut.

Sidney Weiser developed a crystal axis laser scanner that determines the orientation of the crystal axis in single-crystal semiconductor materials.

Weiser's device will be manufactured commercially by Exotech Incorporated of Gaithersburg, Md., and is expected to cost from $25,000 to $85,000, depending on features.

Mary McKnight, Jonathan Martin, Edward Embree, and Dale Bentz (seated) are shown with the infrared emission surface profilometer used in their technique to measure surface roughness.

Surface Roughness Measurement

Four NBS researchers shared an I-R 100 award for their development of an automated technique using thermography to measure the roughness of surfaces and find defects. The procedure is faster and more versatile than current methods.

Being able to measure surface profiles and detect defects is important for quality control in industries such as electronics, automotive, ceramics, and construction. The NBS technique should be adaptable to in-line inspection since the measurements are made quickly, without touching the surface, and the instrumentation requires little calibration.

In the NBS method, the material to be inspected is heated slightly

Gerald Blessing, with Martin Jones, designed a technique for evaluating ceramic powders during production.

and the resulting emissions are detected by an infrared thermographic camera. Using a microcomputer-based image processor, the thermographic image can be converted to an equivalent topographic map of the surface. Accompanying software mathematically describes surface roughness and isolates defects.

The technique was developed initially to measure very rough surfaces, such as steel which has been blasted with an abrasive like sand. But the NBS researchers are confident it also can measure the roughness of much finer surfaces. In addition, they have used it to find defects, such as rust spots under paint on metal surfaces.

Mary E. McKnight, Jonathan W. Martin, and Edward J. Embree of the NBS Center for Building Technology and Dale P. Bentz, now with the W.R. Grace Corporation, developed the technique.

Ceramic Quality Sensor

Martin P. Jones, formerly of NBS, and Gerald V. Blessing of the NBS Center for Manufacturing Engineering won an I-R 100 award for the development of a new ultrasonic method for monitoring the quality of ceramic powders during compaction. The sensor is the first nondestructive evaluation technique that permits ceramic producers to fully automate the inspection of compacted powders while the material is in the mold.

The sensor system uses piezoelectric transducers to generate ultrasonic wave pulses that travel through a mold and into a sample. The resulting ultrasonic echoes are recorded as they reflect back and forth through the material until the pulses die out. The sensor, which is sensitive to porosity, moisture, and chemical content, offers producers a way to control the quality of ceramic powders at almost any stage of compaction without having to handle the very fragile materials in their green or unfired state.

The in-situ ceramic quality sensor was developed at NBS as part of the Bureau's effort to apply nondestructive evaluation techniques to measure the properties and characteristics of materials for in-line monitoring and process control during manufacture. Jones, who now works for Alcoa Laboratories, Alcoa Center, Pa., developed the sensor with Blessing while he was a Johns Hopkins University graduate student at NBS.

Pipe Porosity Sensor

An industry-government team was given an I-R 100 award for the development of another ultrasonic sensor technique that will enable steel producers to quickly detect flaws in hot metal and more accurately crop unsound material before it is run through the complete production cycle.

The sensor, which has the potential for saving the U.S. steel industry millions of dollars annually, was developed under a cooperative agreement between NBS and the American Iron and Steel Institute (AISI) and evaluated and tested at Argonne National Laboratory. It is based on an ultrasonic system developed for AISI by the Magnaflux Corporation of Chicago.

The Magnaflux system uses contact rollers that require heavy pressures (10,000-20,000 pounds per square inch) to transmit high-frequency sound waves into hot steel.

Melvin Linzer (left) and Haydn Wadley were part of an industry-government team that developed a sensor for detecting flaws in hot steel.

Top. Honored for their digital composition mapping system were (from left) David Bright, Ryna Marinenko, Dale Newbury, and Robert Myklebust.

Bottom. H.M. (Skip) Kingston and Lois Jassie designed a microwave system for dissolving chemical samples in closed containers.

Melvin Linzer of NBS modified this system by placing a powder flux—which melts at high temperatures—in front of the rollers. This eliminates the need for heavy wheel pressures to couple ultrasound pulses into and out of hot steel blooms, billets, and slabs. The award-winning technique uses a piezoelectric transducer that is isolated from the hot steel surface by a buffer rod. The powder flux is used as a liquid couplant to provide excellent acoustic contact between the rod and the hot steel surface.

The other members of the research team include Haydn N.G. Wadley, NBS Metallurgy Division; Lev Spevak, Magnaflux Corporation; David S. Kupperman, Argonne National Laboratory; and C. David Rogers, United States Steel, USX Corporation, and AISI program manager at NBS.

Digital Compositional Mapping

A team of eight researchers from NBS and the National Institutes of Health (NIH) was honored for the introduction of a system that uses digital computer technology coupled with electron beam instruments to "map" the distribution of chemical elements on the surfaces of a variety of samples.

The key advantage to the system is that it can create compositional images which display both the type and number of atoms at sample sites 1 micrometer or finer in dimension. That is, besides giving qualitative information on which elements are distributed in the sample, the system also provides a complete quantitative analysis at every 1-micrometer-wide point. The researchers can view these dual functions through a color-enhanced video image of the sample. Other devices on the market are limited in their ability to provide a complete quantitative analysis.

The system has many applications, including characterization of microstructures in various materials and the linking of disease to chemical imbalances in the body.

The digital compositional mapping system was developed by Ryna B. Marinenko, Dale E. Newbury, Robert C. Myklebust, and David S. Bright of the NBS Center for Analytical Chemistry and Charles E. Fiori, Richard D. Leapman, Carol R. Swyt, and Keith E. Gorlen of NIH.

Microwave Dissolution

H.M. (Skip) Kingston of the NBS Center for Analytical Chemistry and Lois B. Jassie, Michael J. Collins, and Ronald J. Goetchius of CEM Corporation, a North Carolina manufacturer of research microwave equipment, shared an I-R 100 award for their design of a system that uses microwaves to rapidly dissolve chemical samples in closed vessels. Sample dissolution is the first step in most instrumental elemental analysis.

The new system is an improvement over traditional dissolution techniques. It is rapid, safe, and contaminant-free, factors essential to reliable chemical analyses. By combining the microwave technique's ability to directly couple energy and heat materials quickly with the superior dissolving properties of closed containers under pressure, the NBS/CEM team has designed a method for decomposing samples that takes less than 15 minutes. Older hot plate methods using open-vented beakers typically require dissolving times of anywhere from 4 hours to 4 days, depending on the complexity of the sample.

Kingston and Jassie are editing a book for the American Chemical Society that will allow industrial chemists to predict conditions and safely tailor their own microwave devices for desired results.

Matching Processor and Algorithms:
The Challenge of Parallel Computers

Parallel processors are the new stars on the horizon of computing. With a handful of thousands of separate calculating engines (processors) linked together, these new computer architectures promise to replace single processors as the workhorses for number-crunching scientists and engineers. Unfortunately, mathematicians and computer scientists are just beginning to understand how best to program these new machines.

Francis Sullivan, director of the Center for Applied Mathematics (CAM) at the National Bureau of Standards, hopes to clear away

We are going to take a broad look at scientific applications and try to build a taxonomy of problem types says Francis Sullivan, director of the NBS Center for Applied Mathematics.

some of the mists now shrouding the programming of parallel processor computers.* He and his colleagues are particularly interested in computational methods, termed algorithms, used to solve numerical problems. An algorithm is a set of logical directions for calculating an answer, much as a recipe is a set of directions for cooking. The researchers' goal is to run scientific calculations faster by matching an algorithm to a computer's design.

Today, the major tool scientists and engineers use to tackle complex numerical problems is the supercomputer, the crowning glory of electrical engineering's ability to pack circuits more and more closely. The supercomputer's compact, but extremely powerful, processor performs hundreds of millions of calculations per second—one calculation at a time. This speed lets these machines obtain answers once thought beyond reach.

A problem that would take weeks or months to solve on a personal computer can be solved in minutes or hours on a supercomputer. Chemists use these machines to calculate the behavior of molecules from the laws of quantum mechanics; meteorologists depend on supercomputers to simulate the atmosphere for accurate, long-term weather forecasts; engineers designing aircraft simulate the airflow around a wing or fuselage with a precision previously obtained only in a wind tunnel.

"The existence of supercomputers has broadened everybody's horizons," says Sullivan. But, their relatively high cost puts supercomputers beyond the means of most researchers and companies. In addition, computer engineers are approaching the limits that the laws of physics impose on the speed of an individual processor. "The next step has to be a radical change in computer architecture, coupled with a lot more thought about how one writes programs," explains Sullivan.

These costs and limitations are driving scientists and engineers to investigate parallel, or multiprocessor, computers as less expensive substitutes for supercomputers.

Traditional, single-processor computers execute only one instruction at a time. In contrast, parallel machines can perform several—or even thousands—of actions at the same time, depending on the number of processors.

This gives even machines with relatively simple individual processors much of the power of a supercomputer at a fraction of the cost. Parallel computers can cost $100,000 or less and are capable of performing 400 million calculations per second, while a traditional computer, which can do a billion calculations per second, can cost as much as $15 million.

"The parallel computers are here," Sullivan observes. "They are not toys. There are hundreds of parallel computers now installed and used for scientific applications." In fact, the fastest computers currently available are parallel supercomputers with, usually, four or eight very powerful processors.

Unlike the single-processor machines, parallel computers come in a wide variety of architectures. Some designs have many processors sharing a common memory; other designs give each processor its own local memory, with no shared memory.

In a single-processor computer one instruction is brought from memory and executed, then the next, and so on. A multiprocessor computer, in contrast, can perform many operations at the same time, letting each processor work on a separate part of a problem. Or it can perform the same instruction simultaneously on more than one piece of data, running its processors in lockstep.

The computer science community is just beginning to match problems in engineering, physics, or chemistry to the parallel computer architecture able to solve them the fastest. Funded by the U.S. Department of Energy and the Office of Naval Research, the National Research Council last year issued a report, entitled *An Agenda for Improved Evaluation of Supercomputer Performance,* emphasizing the importance of this effort.

*This work is in collaboration with the work reported earlier in *NBS Research Reports* (April 1987).

"One thing that the report says is that we don't really know how to evaluate the performance of supercomputers and parallel computers," Sullivan says. "It's about time we began to think very seriously about how to do that."

Historically, computer performance has been measured in terms of the speed of simple computational operations of the central processing unit, a measure not adequate for multiprocessor architectures. Another widely used approach is to take a "typical" calculation—a benchmark—and run it on a variety of machines.

This approach is limited, since information is gathered on only one class of problem, and it may not be representative of other types of computations. What is needed is a method that predicts which architecture will allow the most efficient solution of a given problem.

"There is a fundamental difference between knowing that an application [program] computes on a system for a certain length of time and knowing that the time is well-used," the National Research Council report says. Determining which type of parallel computer will run a scientific problem most efficiently is the task undertaken by Sullivan and his associates in the Center for Applied Mathematics, in collaboration with researchers in the NBS Institute for Computer Sciences and Technology (ICST). Working with them are scientists at the University of Colorado and The University of Maryland.

In this project, which is also sponsored by the U.S. Department of Energy, the researchers will use standard programming languages (FORTRAN and C) adapted to run on parallel computers. Their first step towards their goal is to classify scientific problems and the algorithms used to solve them. One can group problems by their discipline area (chemistry) and problem type (molecular dynamics), but Sullivan considers this approach inadequate.

"What I think is important in looking at problems is trying to understand what the essential problem is—how the data move around and what it takes to perform the calculation," he says. "So part of what we are going to try to do is to take a broad look at scientific applications and try to build a taxonomy of problem types—not by discipline area, but by what the core calculation is.

"It turns out that, if you look at it the right way, you can take areas that seem to be completely different, like fluid dynamics and elementary particle theory, and from the point of view of the kind of algorithm you are working with and the kind of data flow that goes on, they are the same problem."

Once they have built this taxonomy of problem types, Sullivan and his colleagues plan to identify and extract the fundamental portion of the algorithm, the kernel process. They are in a good position to do that because of their involvement with the entire spectrum of computational mathematics.

If the researchers are able to identify six or seven classes of problems and extract the kernel processes, what will they do with them? An obvious idea is to run these fundamental calculations on all possible parallel machines, as benchmarks. Measuring the speed of the algorithm is not enough. Instead, Sullivan hopes to understand what happens when each of these kernel processes is executed in different parallel computers.

He considers it important to establish whether any performance limitations are related to the algorithm itself, the manner in which information is passed between memory and the processors (the communications protocol), or the machine's hardware. Another group of NBS researchers, headed by Robert Carpenter in ICST, has developed hardware to gather information on fundamental events in the hardware of parallel computers. Sullivan's group will contribute to the development of test routines for this equipment.

Using instrumented shared-memory and local-memory parallel machines, the researchers plan to observe basic machine events during execution of the algorithms. A software technique, code profiling, will provide them with additional information. Unlike a benchmark, which tells you how long it took to run the program, a code profile tells where in the program you are spending your time.

"When you actually run a profiler on something, you find out that some little piece of code you hardly ever think about is where you are spending all your time," Sullivan notes. "You need to go in and work on that piece of the program."

From this information, the researchers expect to determine the operations dominating each kernel process. Guidelines based on this data will help computational scientists select the proper machine to run a particular algorithm or choose the best way to implement a specific algorithm on a particular parallel computer.

Rarely is there only one algorithm suitable for solving a scientific problem, so the mathematical method can generally be tailored to the available computer.

"The problems people are facing are not how to integrate differential equations. We know something about that by now," Sullivan says. "The problem is: What is a reasonable way to organize this data so that I can get my algorithm to work efficiently? We hope to be able to answer that question."

by David I. Lewin
Washington, D.C.-area Science Writer

Process Sensor Measures Internal Temperatures in Extruded Aluminum

A process control sensor that rapidly measures the internal temperatures of extruded aluminum as it comes out of a die has been developed by the National Bureau of Standards and the Extruded Products Division of the Aluminum Association. With improved temperature control at the extrusion press, manufacturers will be able to increase the production speed of extruded materials, prevent surface cracking, and improve product yield.

The sensor was produced under a cooperative research program, established in 1986, between the Bureau and the aluminum industry group to develop a process control sensor for the manufacture of extruded aluminum products. Of the more than 16.1 billion pounds of aluminum projected for shipment in 1987 by U.S. manufacturers, nearly one-fifth of the production will be extruded shapes, bars, pipe, and rods.

NBS scientist Arnold Kahn (left) and research associate Michael Mester discuss their process control sensor, designed to be used in the production of extruded aluminum products.

The new process control sensor was designed by Michael L. Mester, an Aluminum Association-sponsored researcher at the Bureau, and NBS scientists Arnold H. Kahn and Haydn N. G. Wadley.

It has been tested by researchers at the Cressona Aluminum Company, Cressona, Pa., where its on-line performance at an extrusion press in a working mill repeated successful laboratory measurements. The scientists were assisted in the Cressona tests by Richard M. Harris, vice president for manufacturing, and a team of production engineers.

The new sensor can measure the body temperatures of extruded aluminum at 500 °C to a depth of one-half the thickness of the material with an accuracy of 5 °C.

Based on an electromagnetic concept, the sensor generates eddy currents in hot aluminum as it is extruded from a die. (Eddy currents are electrical currents induced in a metal by changing magnetic fields.) By measuring the properties of eddy currents in metal, it is possible to determine temperature. With the new sensor, electromagnetic signals from the extruded material are recorded by a computer and rapidly processed to show temperatures for on-line process control.

According to Wadley, NBS head of the project, the process control device is the first non-contact method to accurately measure the body temperatures of extruded hot metals.

Mester points out that the sensor has potential in the production of non-magnetic steels, copper, and metal alloys. It could be used in other manufacturing processes such as the rolling and drawing of metals.

Kahn explains that the automated system also is designed to measure the dimensions of extruded materials as they come out of the press. This additional capability could be used to provide information on die wear during extrusion runs and for other dimensional sensor needs such as in hot isostatic pressing.

The testing of the prototype sensor on an extrusion press completes the first part of the multi-phase program between NBS and the Aluminum Association.

Robert I. Werner, chairman of the Aluminum Association's Extruded Products Division Research Task Group, says, "We are pleased with the successful Cressona tests. The sensor was developed on time, within budget, and it withstood the rigorous demands of a working mill environment."

Werner says that the next step by the task group will be to offer the sensor design to instrument builders for development into a production system.

John C. Bard, president of the Aluminum Association, says, "The program between NBS and our group is an example of how industry and government can work together to improve our nation's industrial competitiveness. This new process control sensor will offer producers improved quality control throughout the entire manufacturing process and eliminate 'guesswork' in several critical areas."

The program between NBS and the Aluminum Association is one of many such cooperative undertakings with industry at the Bureau. In the metals area, a similar agreement between NBS and the American Iron and Steel Institute has produced a prototype ultrasonic sensor for detecting flaws in hot steel billets, and has made possible another ultrasonic sensor technique for reading internal temperature profiles in metals.

The Aluminum Association, headquartered in Washington, D.C., is a national organization of 87 aluminum producers and fabricators of materials and products for industry, construction, and consumers.

by Roger Rensberger
NBS Public Affairs Specialist

Life, Death, and Oxygen Radicals

At the 4th International Congress on Oxygen Radicals, scientists from around the world considered the delicate balancing act of life in a corrosive environment.

A number of science fiction authors have speculated that inquiring aliens might well write the Earth off after a cursory inspection because of its corrosive, lethal atmosphere. We usually think of oxygen as beneficial, necessary to life. It is also a killer.

Last June more then 400 researchers gathered from all around the world in La Jolla, Calif., to discuss the paradoxical, dark aspect of oxygen chemistry at the 4th International Congress on Oxygen Radicals (ICOR), organized by the National Bureau of Standards. Other sponsors of the congress were the National Heart, Lung and Blood Institute; the International Life Sciences Institute; the National Cancer Institute; the American Industrial Health Council; and the Institute for Research on Aging. Seventeen major corporations and industrial associations also contributed funds.

The meeting's arcane title belied the universality of its topics, for the chemistry of oxygen radicals is now believed by many researchers to play a crucial role in a host of generally undesirable processes, including food spoilage, aging, cancer, arthritis, atherosclerosis, various eye and lung disorders, tissue damage following strokes or heart attacks, and a growing list of other afflictions.

Oxygen radicals also play a role in several beneficial things, such as the action of some antibacterial drugs.

Oxygen radicals are highly reactive chemical groups derived from oxygen. They are produced in a variety of ways including chemical and biochemical reactions and by radiation. They are generally present for only a fraction of a second before they react with some other molecule.

Michael Simic of the NBS Center for Radiation Research chaired the congress. He explains that the interest in oxygen radical processes in biochemistry is a comparatively recent phenomenon.

"In the 1950's and 1960's there was a lot of interest in food systems. Things that are kept refrigerated, by and large, spoil chemically. Food chemists were interested in enzyme reactions that generated free oxygen radicals, which then lead to the reactions that cause rancidity and spoilage," he says.

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The role of oxygen radicals in biochemistry was largely unconsidered until the late 1960's when researchers Joseph McCord and Irwin Fridovich of Duke University demonstrated the existence of a naturally occurring enzyme, superoxide dismutase (SOD) which seems to have no purpose other than to convert the simple oxygen radical superoxide to the more stable forms of hydrogen peroxide and molecular oxygen. The existence of SOD's suggested that the superoxide radical, at least, is so prevalent in biochemical systems that enzymes have evolved to deal with it.

"In the 1980's, things accelerated tremendously," says Simic. Biologists who were coming up with more and more evidence for the role of oxygen radicals in living systems hooked up with chemists who had long experience in handling these species. Radiation chemists, for example, contributed their experience in the behavior of the extremely important hydroxyl radical (formed by the dissociation of water).

Indeed, one of the main reasons for the four ICOR meetings held since 1977 has been to bring together researchers from normally widely separated disciplines to exchange notes. The June meeting included physicists, chemists, biologists, and physicians, as well as specialists in food chemistry, clinical chemistry, and pharmacology. "It is a very fertile time for these combined conferences." Simic adds.

The last two decades of research have revealed a still-incomplete picture of oxygen radicals intimately involved in a host of biochemical processes, both good and bad. "When you talk about free radicals in biological systems, you have to come to grips with a couple of things," observes Ajit Singh of Atomic Energy of Canada, Ltd., who organized the first ICOR. "First, in biological systems, free radicals are usually under control. The body knows how to deal with them, and they are doing a job for the body. When we overload the body's systems, for example by radiation, we may overwhelm the body's ability to deal with free radicals."

"Life is a tightrope act," agrees colleague William Lands of the University of Illinois, known for his work on oils in the human diet. "There is a delicate balance in the response to stimuli."

A principal goal of the researchers who gathered in La Jolla is to understand the role that oxygen radicals play in this balance, and what happens when things go awry.

Some samples:

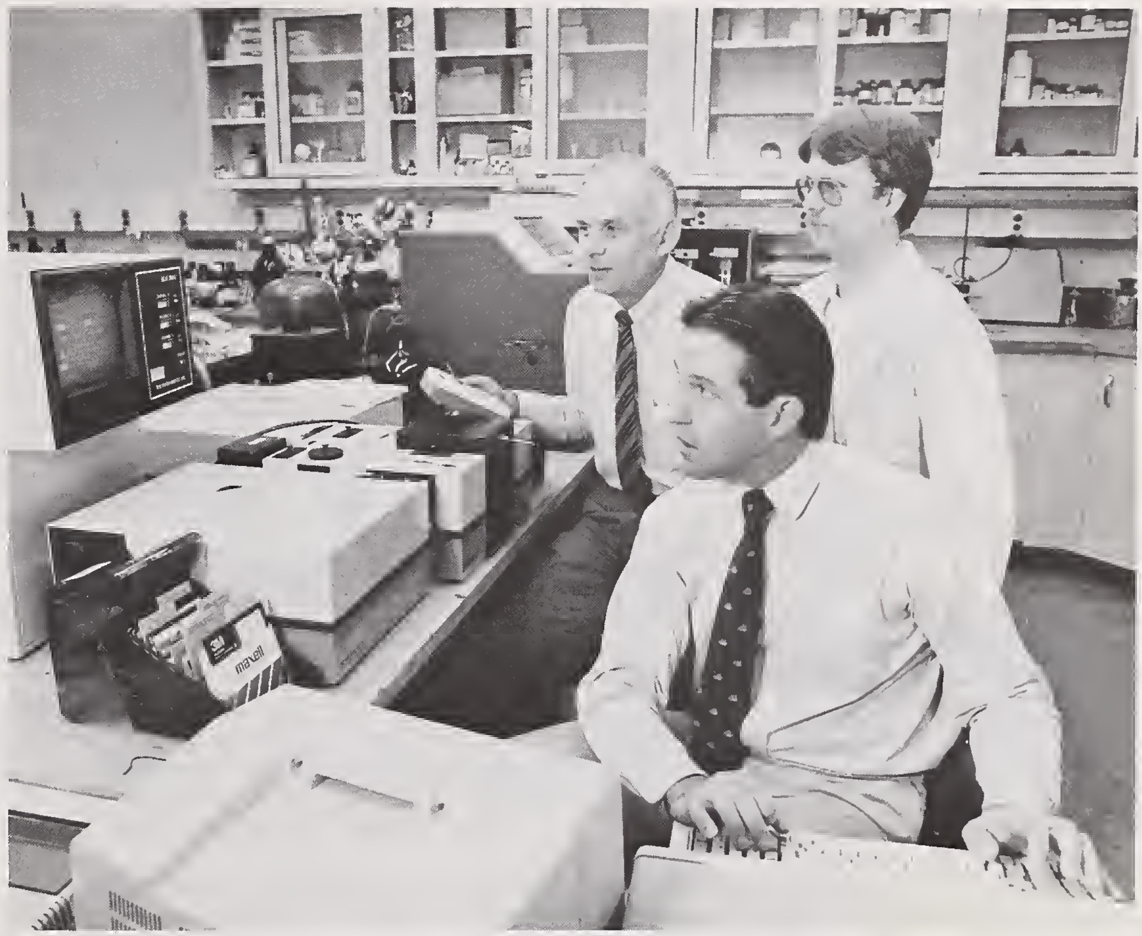
☐ Lands is studying the importance of balancing the kinds of fats in the diet. By far the most common fats in the American diet are so-called "n-6 fatty acids," found in almost all vegetable oils, including corn, soybean, and safflower, and in the flesh of animals fed those grains. Although important to the body's mechanism of cell messenger molecules, says Lands, an excessive imbalance of these oils, and their biological products, has been implicated in a rogues' gallery of diseases ranging from headaches, menstrual cramps, and hypertension through heart disease, stroke, coronary thrombosis, and cancer.

Many of these effects apparently can be mitigated, according to Lands, by diminishing the use of n-6-type oils and increasing the intake of n-3-type oils found in green, leafy vegetables and, in particular, seafood. Too much of the latter, however, seems to interfere with the useful aspects of n-6 fats, leading to such things as hemorrhagic stroke.

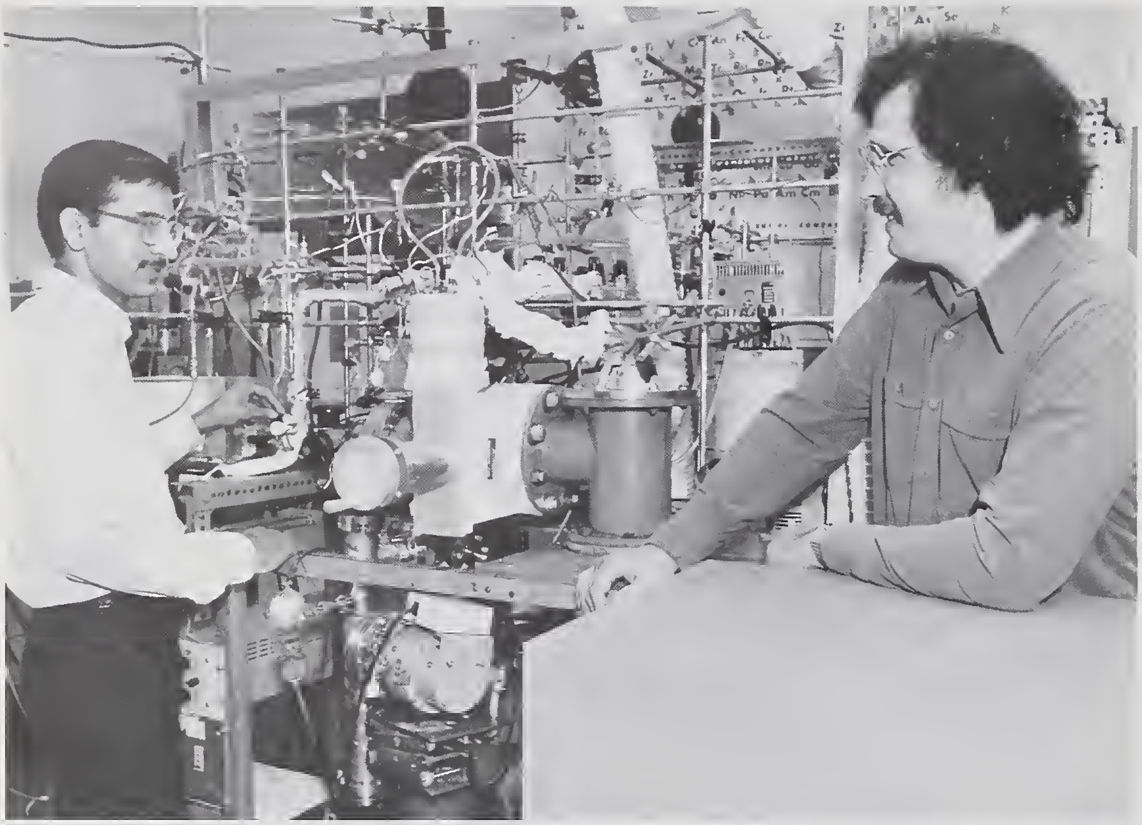
☐ A paper presented by Kelvin Davies and Susan McKenna from the University of Southern California offers an explanation of the mechanism by which "neutrophils" in the blood attack and destroy invading bacteria. According to their theory, the neutrophils initiate a rapid chain of reactions, beginning with the conversion of molecular oxygen to superoxide radicals and ending with the production of hypochlorous acid—common laundry bleach. This "bleach" then attacks the DNA and RNA synthesis mechanisms in the bacteria, destroying its ability to reproduce. This allows the neutrophils to dismantle it at leisure.

☐ A growing body of evidence, much of it discussed at this meeting, implicates uncontrolled free radicals in a variety of diseases, including the two major killers in Western nations: atherosclerosis and cancer. Although still somewhat controversial, an increasing number of researchers believe that many of the basic effects of aging are due to the gradual accumulation of the products of reactions of oxygen radicals with cell components.

☐ Vitamins E and C are increasingly seen to be important in protecting cells from the harmful effects of oxygen radicals. Vitamin E, embedded in the cell's membranes, sacrifices itself to break an otherwise cell-lethal chain reaction initiated by oxygen radicals. Vitamin C, found in fluids outside the cell,



NBS radiation chemists Michael Simic (left) and David Bergtold and guest scientist Ambler Thompson of The University of Maryland, Baltimore County (foreground) use a spectrofluorimeter to analyze the products of oxygen-related free-radical reactions.



NBS research chemist Stephen Stein (right) and guest scientist Mahendra Suryan of West Virginia University with the apparatus used to measure chemical bond strengths in models for antioxidants such as vitamin E. Bond strengths are important in understanding the kinetics of these molecules. Their work is supported by the Gas Research Institute.

sacrifices itself to repair the damaged vitamin E.

☐ Gregory Bulkley and his colleagues from Johns Hopkins University presented what may be the first direct evidence in a living system of the action of oxygen radicals in damaging organs that have been deprived of blood and then resupplied. This phenomenon, called "ischemia" (blood deprivation) and "reperfusion" (resupply), has received much attention recently because it seems to be one of the primary ways in which the brain, heart, and other organs are damaged after strokes, heart attacks, surgery, or other events that temporarily halt blood supply. Oxygen-free radicals have been the chief suspects in the process, and the Johns Hopkins team reports the detection of the extremely low levels of light that are generated by free radical reactions, called chemiluminescence, in intact, living organs at reperfusion. Drugs that limit the action of the radicals in these cases may dramatically improve the chances of stroke victims to achieve full recovery.

☐ Hyperbaric oxygen chambers, which involve breathing almost pure oxygen under pressure, are seen by some researchers as needlessly risky save in the treatment of certain conditions such as gas gangrene or stroke. Elevated levels of oxygen at high pressures bring on convulsions and death in lab animals, according to University of New South Wales researcher Dana Jamieson, with oxygen radical-mediated processes in both the lungs and brain vying to bring on death. "If you think of oxygen as a drug," observes Jamieson, "it has a very low therapeutic ratio. It would be difficult or impossible to get it approved by the FDA."

Although NBS is not known for biomedical research, Bureau researchers contributed to several different sessions of the congress. Typically, NBS research concentrates on obtaining basic chemical data and developing measurement techniques.

Steven Stein of the NBS Center for Chemical Physics, for example, presented basic research results on the thermochemistry and kinetics of the important class of phenoxyl radicals—hydrogen-oxygen radicals which include a benzene group. "We've done a long series of studies to be able to predict the bond strengths in phenols on the basis of their structure," explains Stein. "Typical phenols and their radicals are quite important in biosystems, such as vitamin E, which prevents the oxidation of cell membranes. Ultimately you'd like to be able to predict, for example, the antioxidant activity of a compound based on its structure."

Ambler Thompson, an NBS guest researcher from The University of Maryland, chaired an ICOR session on his specialty—chemiluminescence, the study of chemical and biochemical reactions that produce light.

Typically, NBS research concentrates on obtaining basic chemical data and developing measurement techniques.

Chemiluminescence is an emerging technique with great potential for creating tailored chemical systems that can monitor directly oxygen radical reactions in living systems by the light they produce. Bulkley and his colleagues at Johns Hopkins used chemiluminescence in their study of oxygen radical reactions during reperfusion. "Given modern photon-counting methods, which are capable of detecting photon-emitting chemical species at a level of 1 in a trillion, chemiluminescence can be an extremely sensitive, noninvasive analytical technique—theoretically more sensitive than radioisotopes," says Thompson.

The combination of specialists from a wide variety of disciplines and an array of sophisticated and often rare experimental facilities makes NBS an excellent place to do the basic research required by a multidisciplinary field like oxygen radical biochemistry, according to Simic.

"Our pulse radiolysis facility is a good example," he notes. "Pulse radiolysis allows you to generate specific free radicals, in high concentrations, and follow their reactions with very high time resolution."

"Food oxidation takes several weeks. Pulse radiolysis compresses that to less than 1 microsecond, with the reaction products formed in milliseconds. You can get information you can't get by any other method. There are only four other places in the United States where you could do this."

Slobodan Jovanovic, an NBS guest researcher from the Boris Kidric Institute of Nuclear Sciences in Yugoslavia, has been working with Simic to measure redox potentials for a variety of compounds of interest to the congress—data that relates to the ability of the compound to participate in a given chemical reaction.

"In order to make useful models of an antioxidant for a given system, you first need to know what kind of species are causing trouble, and second what mode of reaction would those species preferentially follow," notes Jovanovic. "This is very basic research, but it helps put theories on a sound scientific basis. What we are doing now may help in the development of antioxidants for food and plastics, and it also has application to certain biochemical studies in, say, cancer research or nutrition."

"Of paramount importance," says Simic, "is the fact that all these life processes are in a very complicated system of equilibrium and balance. We have to consider the mechanisms of these processes in order to make major steps forward. By mechanisms we mean thermodynamics—what reactions are possible, kinetics—how fast do they occur, and what products are generated—measurement at the molecular level.

"Our understanding of basic oxygen radical chemistry is fairly good, although some more work is needed, but what is really missing is the effect of parameters in living systems on the balance of free radicals. How many years is it since the beginnings of radiation biology? We still don't understand the oxygen effect—with oxygen present the killing of cells is greatly potentiated, by factors of two to four.

"We don't understand these phenomena because coupling between the biological system and the simplest level of understanding doesn't exist. We don't yet have the proper mechanisms to study free radicals in living systems.

"What we are doing now may help in the development of antioxidants for food and plastics, and it also has application to certain biochemical studies in, say, cancer research or nutrition."

"This is where we come in. Once you understand the great importance of studying mechanisms, you need to detect, measure, and standardize the species involved. That is what we do here at NBS." M.A.B.

New Technique for Evaluating Installation of Home Insulation

NBS researchers are completing testing of a new measurement technique, based on acoustics, that shows considerable promise for quality control in the manufacture of insulation and could also be the basis for efficient, low-cost tools for evaluating loose-fill attic insulation after it is installed.

Loose-fill thermal insulation is a light, fluffy material—typically fiberglass, mineral fiber (rock wool), or treated cellulose—which is installed in attics, crawl spaces, or walls by blowing or pouring the fiber into the space to be insulated. Measurement difficulties in assessing loose-fill insulation have raised concerns about problems with quality control and consumer protection.

The effectiveness of home insulation is measured in terms of its thermal resistance, or "R-value." Directly measuring the R-value by classical thermal techniques typically requires several hours in the laboratory and several days under field conditions. The uncertainty of R-value measurements made under field conditions also may be quite large. For these reasons, it has been customary to measure a quantity—the coverage in pounds per square foot—that is related to the R-value of installed insulation rather than to measure the R-value directly.

For a given insulation product, the R-value depends upon the thickness and the density of the insulation after it is installed. At present, the only practical field method for determining the coverage of loose-fill insulation involves measuring its thickness at multiple locations in the attic, taking core samples at each of these locations using a tool resembling a giant cookie cutter, removing the insulation samples in plastic bags, weighing them, calculating the density, and then replacing the samples.

Researchers in the NBS Center for Manufacturing Engineering—funded by the Mineral Insulation Manufacturers Association, the U.S. Department of Energy, and NBS—have developed a high-speed method for indirectly measuring either the coverage or the R-value of certain types of loose-fill insulation by passing sound waves through a sample of material and measuring the sound insertion loss (i.e., the decrease in sound level) caused by the insulation at various frequencies.

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In the laboratory system developed by the acoustic measurements group at NBS, pulses of sound containing energy in the frequency range of 2.5 to 25 kilohertz are projected through a sample of insulating material. The samples of insulation are contained in individual baskets which have acoustically transparent bottoms and are supported inside a specially designed test chamber.

The sound insertion loss of loose-fill insulations has been found, for a given insulating material, to correlate quite well with the coverage (mass per unit area) of the material, particularly for fiberglass materials. Predicting coverage of rock wool insulation is somewhat problematic, according to researchers, because of the presence of fused material.

When comparing results obtained for the R-values of a variety of samples of insulation using the extremely accurate 1-meter guarded hot-plate designed and built in the NBS Center for Building Technology with results obtained for the sound insertion loss of the same samples, good correlation was found between the results of the two methods.

Researchers say that a version of the laboratory apparatus used at NBS could be useful to insulation manufacturers for quality control. The acoustic test apparatus collects and analyzes data in a few minutes and yields results that would require several hours to obtain using thermal measurement procedures.

Moreover, they say, the principles could be applied to field instrumentation for characterizing insulation installed in attics by using acoustic probes either suspended over the insulation, or inserted into the insulation through holes bored in the ceiling. NBS researchers, Gerald V. Blessing and Daniel R. Flynn, have been granted a patent for various design concepts for a field instrument utilizing these ideas.

The NBS results have been presented to ASTM Committee C16 on Thermal Insulation, which is interested in the acoustic technique as a possible ASTM test method. In addition, ASTM has agreed to coordinate an effort to raise the funds needed to develop a practical field instrument based on acoustic measurements of installed loose-fill insulation. M.A.B.

NEW PUBLICATIONS

DUPONT PLAZA HOTEL FIRE

Nelson, H.E., ***An Engineering Analysis of the Early Stages of Fire Development—The Fire at the Dupont Plaza Hotel and Casino, December 31, 1986,*** *Natl. Bur. Stand. (U.S.), NBSIR 87-3560, 113 pages (April 1987). Order by stock no. PB 87-201828 from NTIS, $18.95 ($37.50 foreign) prepaid.*

On December 31, 1986, a fire in the Dupont Plaza Hotel in San Juan, Puerto Rico, killed 98 people. As part of the federal team investigating the fire, scientists and engineers from the NBS Center for Fire Research used tools developed through a decade of research to calculate the course of the fire. The results showed that once set, the fire spread from the ballroom through the first two floors of the hotel killing most of the victims in 10 to 15 minutes. Had this fire growth analysis been done to test the building design, say the researchers, it would have shown that the glass partitions separating the ballroom from the hotel lobby were insufficient to resist this fire. Also it would have shown that both of the exits from the casino, where most of the victims died, could be quickly blocked by the fire. The NBS researchers also calculated what would have happened if sprinklers or smoke detectors had been present. The NBS investigation represents a new approach to fire analysis, say the researchers, and demonstrates how these tools can be used to both investigate and prevent fires.

MEASURING FAULTS IN PARALLEL PROCESSORS

Roberts, J.W., Mink, A., and Carpenter, R.J., ***On the Measurement of Fault-Tolerant Parallel Processors,*** *Natl. Bur. Stand. (U.S.), NBSIR 87-3568, 49 pages (May 1987). Order by stock no. PB 87-208328/AS from NTIS, $11.95 prepaid.*

In a recent study for the Defense Advanced Research Projects Agency, NBS researchers investigated a number of measurement techniques that can be used to detect and recover from hardware faults in parallel processors. "Fault-tolerance" is particularly important in computer systems used, for example, to solve large problems such as weather forecasting and to control aircraft and spacecraft. The researchers looked at ways to detect transmission and data storage errors and faults in processors, controllers, computer components, and input/output systems.

NBS MEASUREMENT SERVICE FOR NEUTRON PERSONNEL DOSIMETERS

Schwartz, R.B., ***NBS Measurement Services: Neutron Personnel Dosimetry,*** *Natl. Bur. Stand. (U.S.), NBS Spec. Pub. 250-12, 44 pages (July 1987). Order by stock no. 003-003-02811-8 from GPO, $2.50 prepaid.*

The calibration and related measurement services of NBS are intended to assist the makers and users of precision measuring instruments in achieving the highest possible levels of accuracy, quality, and productivity. NBS offers over 300 different calibration, special test, and measurement assurance services. These services allow customers to directly link their measurement systems to measurement systems and standards maintained by NBS. This supplemental guide provides a detailed description of the important features of this specific calibration service. It describes the preparation and calibration of neutron dosimeters and remmeters with californium neutron sources, both "bare" and moderated. Corrections for scatter, room-return, anisotropic neutron emission, and deviation from the inverse square law are discussed with specific examples given.

MOTOR FUEL QUALITY

Brickenkamp, C.S., editor, ***Uniform Laws and Regulations,*** *Natl. Bur. Stand. (U.S.), NBS Hdbk. 130—1988, 192 pages (September 1987). Order by stock no. 003-003-02814-2 from GPO, $10 prepaid.*

The latest edition of this NBS handbook contains two new recommendations for motor fuels that were adopted by the National Conference on Weights and Measures (NCWM) at the 72nd annual meeting. Both the "Uniform Motor Fuel Inspection Law," and the "Uniform Regulation for Motor Fuel," require registration of motor fuel and certification that meets ASTM standards. The law would establish a motor fuel quality testing capability by any state that adopts it. The handbook also contains recommendations for other uniform laws and regulations. There is a basic weights and measures law that establishes standards, authorities, and duties of the states for legal metrology, and a weighmaster law. The regulations include packaging and labeling, method of sale of commodities, unit pricing, registration of servicepersons and service agencies for commercial weighing and measuring devices, open dating, and a regulation for national type evaluation.

MASS FLOW METERING STANDARDS

Oppermann, H.V., editor, ***Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices,*** *Natl. Bur. Stand. (U.S.), NBS Hdbk. 44—1988, 301 pages (September 1987). Order by stock no. 003-003-02820-7 from GPO, $15 prepaid.*

The producers and distributors of fuels, lubricants, and petrochemicals will be interested in the changes made to the codes for "Liquid Measuring Devices" and "Liquid Petroleum Gas (LPG) and Anhydrous Ammonia Liquid Measuring Devices" added to this NBS handbook. The National Conference on Weights and Measures (NCWM) adopted the standards at its 72nd annual meeting to recognize the use of mass flow metering systems. Mass flow metering systems that are affected by changes in the density of the product being measured must incorporate an automatic means to determine product density and correct for changes in density while the product is being measured. The tolerances for mass flow meters are consistent with those for other meters used in the same application.

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 the order with payment to Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. ■

CONFERENCE CALENDAR

Fourth International Symposium on Resonance Ionization Spectroscopy and Its Applications, NBS, Gaithersburg, MD

April 11-15, 1988

The RIS-88 symposium is a major forum for the presentation of results of multidisciplinary research involving resonance ionization phenomena and related laser applications. The program will consist of posters, contributed and invited papers, and plenary lectures on the following topics: photophysics and spectroscopy; resonance ionization mass spectrometry (RIMS); molecular resonance ionization spectroscopy; noble gas atom counting; analysis of materials and surfaces; medical and environmental applications; optical sources; atom reservoirs and sampling; physics applications, including elementary particles and nuclear processes; and chemical applications, including diffusion, reactions rates, and clustering. Sponsored by NBS, this symposium is organized by an International Advisory Group through an appointed program committee and is coordinated by the Institute of Resonance Ionization Spectroscopy of the University of Tennessee. Contact: Thomas B. Lucatorto, A243 Physics Building, NBS, Gaithersburg, MD 20899, 301/975-3734.

4th International Conference on Metrology and Properties of Engineering Surfaces, NBS, Gaithersburg, MD

April 13-15, 1988

Metrology and properties of engineering surfaces have continued to assume great importance to both the practicing engineer and the researcher. In recent years, industry has gained increased awareness of the importance of surface preparation techniques. This international conference is the fourth in a series of meetings, held every 3 years since 1976, on metrology and properties of engineering surfaces. The main topics to be discussed at this meeting will be: the application of new surface techniques in industry; the development of new tactile instruments; the development of new techniques for the optical measurement of engineering surfaces; the compilation and analysis of data for specific manufacturing processes; and the relationships between surface generation and practical performance. Sponsored by NBS, Coventry Polytechnic, and Whitestone Business Communications. Contact: K.J. Stout, Coventry Polytechnic, Department of Manufacturing Systems, Priory Street, Coventry CV1 5FB, England, 0203 24166, ext. 278; or Theodore V. Vorburger, A117 Metrology Building, NBS, Gaithersburg, MD 20899, 301/975-3493.

Microstructure and Macromolecular Research with Cold Neutrons, NBS, Gaithersburg, MD

April 21-22, 1988 (NOTE DATE CHANGE)

A major expansion of the neutron scattering facilities at the NBS 20-megawatt research reactor is now under way. The Cold Neutron Research Facility (CNRF), scheduled for completion in 1989, will provide cold neutron beams for many new types of experimental facilities including several with specialized capabilities for the study of structure and dynamics of materials.

The CNRF is intended to be a national facility serving a broad-based community of researchers in materials science, physics, chemistry, and biology. In an effort to inform and involve this community at an early stage while conceptual and detailed planning for instrumentation for the facility is progressing, NBS is hosting a series of workshops, each of which will deal with a major area of cold neutron research. This workshop will focus on the scientific opportunities in the study of submicron structures in materials, including macromolecular structures in polymers and biomaterials, which arise from experimental techniques that take special advantage of cold neutrons. Sponsored by NBS. Contact: Kathy Stang, A345 Physics Building, NBS, Gaithersburg, MD 20899, 301/975-4513.

Twenty-Seventh Annual Technical Symposium of the Washington, D.C., Chapter of the Association for Computing Machinery—Productivity: Progress, Prospects and Payoff, NBS, Gaithersburg, MD

June 9, 1988

Productivity is a key issue in the information industry. Information technology must provide the means to maintain and enhance productivity. This symposium will explore the theoretical and practical issues in developing and applying technology in an information-based society. How productive are we? How productive can we become? What are the inhibitors and facilitators? Sponsored by the Washington, D.C., Chapter Association for Computing Machinery and NBS. Contact: Wilma Osborne, B266 Technology Building, NBS, Gaithersburg, MD 20899, 301/975-3339.

Tenth Symposium on Thermophysical Properties, NBS, Gaithersburg, MD

June 20-23, 1988

This symposium is concerned with theoretical, experimental, and applied aspects of thermophysical properties for gases, liquids, and solids. Topics to be included in the symposium are: thermodynamic properties; transport properties; optical and thermal radiative properties; interface properties; and data correlation. Special topics will be: properties of new materials; properties of gaseous and liquid mixtures; new developments in experimental techniques; and interpretation of experimental data in terms of new theoretical developments. Sponsored by the American Society of Mechanical Engineers, NBS, and The University of Maryland. Contact: Ared Cezairliyan, Room 124 Hazards Building, NBS, Gaithersburg, MD 20899, 301/975-5931 or J.V. Sengers, Institute for Physical Science and Technology, The University of Maryland, College Park, MD 20742, 301/454-4117. ■

☆ U.S. GOVERNMENT PRINTING OFFICE: 1988 - 201-597 - 814/72502

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.

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