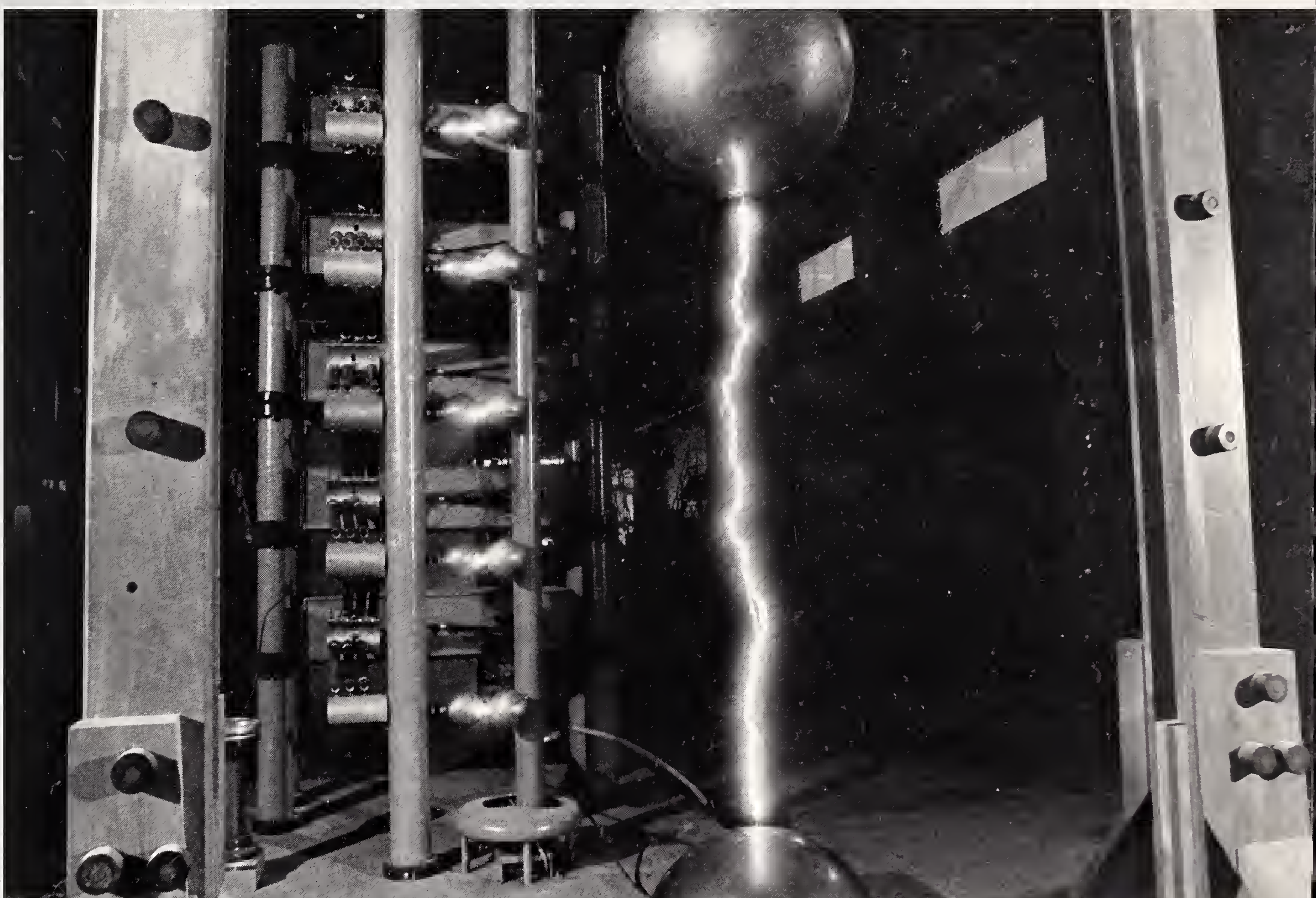
NATIONAL BUREAU OF STANDARDS

NBS Research Reports



U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
NBS SPECIAL PUBLICATION 680-3

Cover photo: This 300,000-volt simulated lightning bolt was produced under controlled conditions in the NBS high-voltage measurement laboratory where researchers help utilities and manufacturers determine what will happen to their equipment if it is struck by lightning. See page 12.

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NBS Research Reports

U.S. DEPARTMENT OF COMMERCE
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MORE ACCURATE MEASUREMENT OF ROBOT PERFORMANCE STUDIED

NBS researchers are developing a new, automated laser-interferometer tracking system which could be the basis for greatly improved measures of the performance of a wide variety of industrial robots. The research prototype makes continuous position measurements while the robot is moving at its normal working pace. The position measurements include not only the three spatial dimensions, but also the pitch and roll of the robot wrist.

Right now, says NBS researcher Kam Lau, the industry suffers because there is no real agreement on how the performance of such machines should be measured. "Each company has its own terms and standards for robot performance, and they are very loosely defined," explains Lau. "We are trying to come up with a series of terms, based on our experience with machine-tool measurements, that will be well-defined and include all the relevant factors in robot performance."

The finished full system device should be able to measure the position of an industrial robot arm, in motion, to an accuracy of 1 part in 100,000. Such a device, Lau says, will be about 100 times more accurate than the best device now available and easier to use. Other applications for the measurement technology include assessing the accuracy of milling machines, lathes, and coordinate measuring machines.

SECURITY OF ELECTRONIC FUNDS TRANSFERS TO BE IMPROVED

The more than $500 billion in federal government collections and payments and $2.5 trillion in federal securities that are transferred electronically each year will be better protected as the result of an agreement signed by NBS, the Department of the Treasury, and the National Security Agency (NSA). The agreement outlines each agency's responsibilities for putting security methods in place by June 1, 1988, as specified in a recent Treasury Department directive. The directive states that federal electronic funds transfers be sealed using the NBS Data Encryption Standard.

Treasury also plans to use an automated system for managing the cryptographic key used to seal the data. One NBS-developed feature of this system notarizes the key with the names of the sender and intended receiver. Based on technical guidance from NSA and NBS, Treasury will certify that electronic funds transfer devices are designed properly and that security features called for in the directive have been incorporated. NBS will develop test methods to validate that the devices comply with the standards in the directive.

NBS OPENS NEW HIGH-INTENSITY GAMMA-RAY FACILITY

A new high-intensity ^{60}Co gamma-ray irradiation facility for high-dose dosimeter calibration work has been set up at NBS. The sample chamber of the new source is 6 inches in diameter and 8 inches high. The absorbed dose rate at the center of the chamber is about 14 kilograys, or 1.4 megarads, per hour. Irradiation times can be preset and terminated automatically. NBS will use the facility to speed high-dose calibration services, but the facility will also be made available to outside users for research programs in dosimetry, radiation chemistry, radiation processing, and the like. For information on scheduling, write or call Dr. James Humphreys, C216 Radiation Physics Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2201.

NBS FILM AVAILABLE

A $13\frac{1}{2}$-minute color film is now available that describes how the National Bureau of Standards uses its measurement expertise to work cooperatively with industry, universities, and other government agencies to help improve U.S. productivity and increase industrial competitiveness. The film, "Measurement: The Vital Link," can be rented from Modern Talking Picture Service, Inc., 5000 Park Street North, St. Petersburg, FL 33709, 813/541-5763, for $15 in 16-mm film, $\frac{3}{4}$-in u-matic videotape, $\frac{1}{2}$-in VHS videotape, or $\frac{1}{2}$-in BETA II videotape.

DEGRADATION OF DENTAL COMPOSITES INVESTIGATED

In work for the National Institute of Dental Research, NBS researchers are investigating various polymer matrices and inorganic fillers to improve the performance of dental composites. They are looking at surface treatments of filler materials to better the corrosion resistance and overall wear. To date, NBS polymer scientists have discovered evidence that inorganic reinforcing fillers used in dental composites corrode. Previously it was thought that the problem with polymer composite restorations was due primarily to degradation of the polymer matrix. Recent NBS investigations on commercial dental composites, conditioned in a simulated oral environment, show signs of dramatic decreases in mechanical wear resistance. This is attributed to corrosion of the inorganic filler material, particularly radiopaque fillers.

TECHNIQUE FOR STABILIZING DYE LASERS IMPROVED

Scientists at NBS and Stanford University have developed an improved laboratory technique for stabilizing the frequency of tunable dye lasers. The technique makes use of a novel frequency transducer which combines an electro-optic phase modulator and an acousto-optic frequency shifter outside the laser cavity. In initial experiments, the researchers have reduced the linewidth of a commercial continuous wave dye laser from about 3 MHz to about 120 kHz with a frequency servo system based on sending the laser output through the transducer. This technique eliminates the disadvantages of other methods, which can be too slow to compensate for the frequency fluctuations in a typical dye laser, inconvenient, or the cause of power loss.

A recent report terms the new transducer "a versatile device which can greatly facilitate the generation of extremely monochromatic light." The device can be used with different lasers without modifying them to include lossy elements inside the laser cavity. With minor additions, the system can also provide intensity stabilization or amplitude/frequency modulation.

SAMPLES TO HELP OIL INDUSTRY DETECT REFINERY "POISONS"

Two of the chemical elements that can impair the petroleum refining process—vanadium and nickel—should be easier to measure reliably with a new Standard Reference Material (SRM) now available from NBS. Designed as a tool for checking the accuracy of a wide range of analytical chemistry instruments, the SRM contains certified concentrations of the two elements at the concentration levels that can cause problems for refiners if present in crude oils and other refinery products. At these levels, heavy metals like vanadium and nickel can "poison"—and possibly cancel—the refining process by reacting with catalysts. With a reliable analysis of content, refiners can adjust the vanadium and nickel in refinery fuels to tolerable levels. The SRM can also be used to analyze such materials as coal-derived oils, kerosene, ethanol mixtures, or jet fuel. SRM 1618, Vanadium and Nickel in Residual Fuel Oil, is available for $103 from the Office of Standard Reference Materials, B311 Chemistry Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2045.

ECONOMIC IMPACT OF AUTOMATION RESEARCH ANALYZED

The contribution of the NBS Automated Manufacturing Research Facility (AMRF) to the increased use of numerical-control machine tools in U.S. industry will produce a savings to the metalworking industry of between $72 and $219 million per year by 1988, according to a report prepared by the Management Collaborative Group of Chapel Hill, N.C. The study of the expected technical and economic impact of the Bureau's automation research program also predicts that this increased use of numerical-control machine tools will save the metalworking industry up to $250 to $760 million each year by 1990. The AMRF, according to the report, "appears to be playing a key role in laying the groundwork for incremental implementation of computer-integrated automated manufacturing by supporting the establishment of standard interfaces between pieces of equipment, and between integrated equipment and a central control system, and by providing the means and methods of in-processing measurement."

The facility includes vertical and horizontal machining workstations, a turning workstation, an automated inspection workstation, and the robotic equipment for a cleaning and deburring workstation. Equipment for the last workstation is expected to be in place by this fall. Over $2.75 millon worth of the equipment in the AMRF was loaned or donated to NBS by companies sponsoring research at the facility.

PATENT AWARDED FOR NEW DISPOSABLE RADIATION DOSIMETER

A trio of researchers from NBS, the Federal Emergency Management Agency, and the U.S. Army have been awarded a patent (#4,489,240) on a new design for a unique, disposable radiation dosimeter that is expected to be particularly useful in radiation therapy. The dosimeter is a thin plastic tube (as thin as 0.8-mm outer diameter) containing a radiochromic dye which takes on a color in proportion to the amount of radiation received. Because this dosimeter has the same response to radiation as body tissue, it accurately measures the dose received by the patient. A transparent plug at one end of the tube and a mirror at the other make it possible to measure the degree of color change by reflecting a light beam through the dosimeter. The dye dosimeter at the end of a fiber optic cable can be placed in specific regions of the body through a conventional catheter. According to the inventors, the dosimeter can be used to make remote measurements of radiation dose to an accuracy of 5 percent—as the dose is being delivered. Improvements are expected to push the accuracy to 2 or 3 percent.

SCIENTISTS REPORT FIRST TRAPPING OF NEUTRAL ATOMS

NBS researchers Alan Migdall, John Prodan, and William Phillips, working with Thomas Bergeman and Harold Metcalf of the State University of New York at Stony Brook, have completed what is believed to be the first successful experiment in "trapping" neutral atoms. The experiment, in which neutral atoms were confined in a magnetic-field trap, is an important advance in the technology of atomic physics. The researchers built on their success in using laser beams to decelerate and actually stop neutral sodium atoms to confine a sample of the atoms in a magnetic trap for at least a second.

"Traps," which use arrangements of electromagnetic fields to hold atomic particles in an observation region for significant lengths of time, are an important tool in atomic physics. Accurate measurements of the properties and behavior of atoms and atomic particles through techniques such as spectroscopy are limited by the speed of the particle. This development opens the possibility of a new generation of experiments in atomic physics. Among the new opportunities are measurements of previously unmeasurably long atomic lifetimes or studies of collisions with very small rates. ■

NBS Research on Polymer Composites:

Laying the Scientific Foundation for Industrial Advance

They are light of weight, ounce for ounce up to five times stronger than steel, and immune to rust. They are easily molded or shaped during processing, an advantage to product designers as well as manufacturers. In final form, they can be rigid and tough enough to serve as a bridge strut, a building support, an auto part, or an airplane wing.

They are a relatively new class of materials called synthetic polymer composites, and yes, indeed, they are very versatile. But their commercial development is being retarded by the absence of basic knowledge—such as a fundamental understanding of how the variables of the manufacturing process affect the properties of the finished materials.

"These are very complex materials," says Dr. Donald Hunston, a polymers physical chemist with the National Bureau of Standards. "And, they are, in many ways, poorly understood, sometimes to the point that manufacturers can't get reproducible results from the fabrication process.

"The difficulties are surmountable," Hunston says. In fact the NBS polymer composites group, which he heads, is making considerable progress in some of the measurement-related aspects of the problem.

The group consists of a core of six NBS researchers, augmented by scientists and engineers from other organizations. They are studying the component materials of composites before processing, exploring what happens during processing and how that affects material performance, and investigating how the finished materials behave and fail.

Dr. Donald Hunston, polymers physical chemist, uses a mechanical testing instrument to study crack growth in advanced polymer matrix composites to improve the strength of resin materials.

The Market Picture

Today in the United States, polymer composites are a $1.3 billion industry, accounting for 5 percent of the entire polymer market. The annual growth rate of the polymer market overall is 5 percent, but polymer composites are growing at double that rate. "Advanced" composites—those used in place of traditional engineering materials such as steel—are growing at a rate of 16 percent a year. In the April 22, 1985, issue of *Chemical and Engineering News,* Anthony J. Cardinal, vice president of Du Pont's Textiles and Fibers Department, says advanced composites could grow at the rate of 30 percent a year, to $10 billion by the year 2000, in the aircraft, aerospace, automotive, industrial, and orthopedic markets.

With such robust market performance, what could possibly be ailing this industry? Hunston explains, "In many areas it operates almost on a custom production, rather than a mass production, basis. The current high rate of growth cannot continue unless manufacturers can increase the speed and reduce the cost of production and improve the reliability of the finished materials. To accomplish these things, they have to acquire the theoretical and data bases needed to improve processing and to predict a material's performance and life expectancy."

Not uncommonly, manufacturers of advanced polymer composites have to reject from 10 to 20 percent of the materials they produce. They simply cannot get predictable, reproducible results, especially when they try to accelerate processing. One major American corporation reports that 80 percent of one of the aerospace parts it produces is rejected by the company's production line quality-control system. Each rejected part must be reviewed individually, by an expert, to determine whether it is acceptable.

To a large extent, at present, the market for advanced polymer composites is the U.S. government. The Defense Department and the National Aeronautics and Space Administration (NASA) in particular require the advantages, especially the one-third to one-half reduction in weight, that polymer composites offer over traditional materials. To no surprise, the Department of Defense and NASA operate large polymer composites laboratories, and collectively they fund a large fraction of NBS' work. Hunston foresees, however, that the commercial market could soon overshadow government demand, particularly if improvements in processing and performance can be achieved.

More on Polymers

Whether organic or inorganic, natural or synthetic, a polymer is a polymer because of the size and internal structure of its molecules. Smaller molecules join chemically in one or more chains of repeating units to form a larger polymer molecule. The spiraling double chain of DNA represents one of an infinite variety of possible structural arrangements.

The overall size of a polymer molecule and its internal arrangement—both the sequence of the components and their spatial relationship—impart certain properties to the material. They account for the brittleness of glass, the gooiness of protoplasm, the resilience of seat cushions, the elasticity of rubber tires, and the toughness of bowling balls.

The synthetic polymer industry began with the development of Bakelite in 1909. Synthetic polymer composites started to appear in the 1940's but the advanced, high-performance composites used today are a more recent development. Essentially, they consist of a polymer matrix, such as an epoxy resin, reinforced with particles or fibers of a different material. The reinforcing agent contributes certain mechanical properties to the finished material, such as improved tensile strength—the extent to which a material withstands a load without tearing apart.

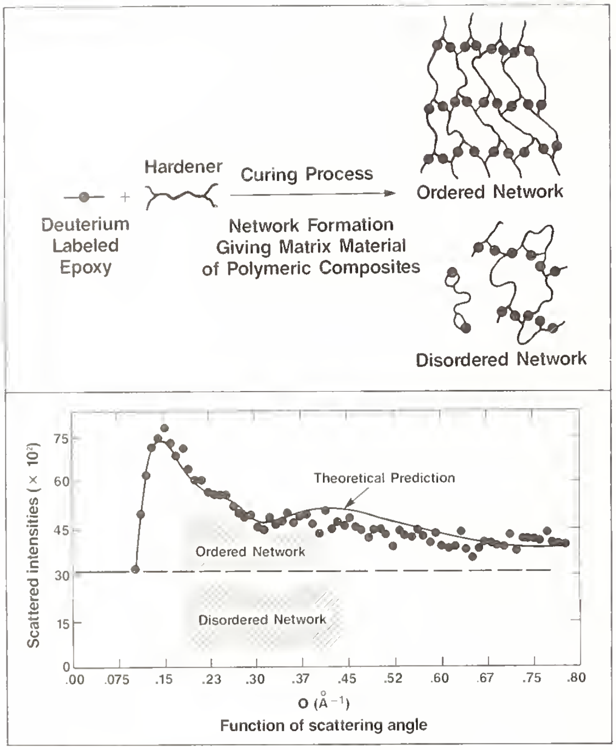
Military planes are now up to 27 percent by weight, 38 percent by volume polymer composites. Some commercial aircraft are already polymer composites in the following proportions: 3 percent by weight and 5 percent by volume. The potential in these aircraft may be 65 percent by weight, 76 percent by volume, but only if composites become predictable enough for use in critical load-bearing applications.

While aerospace applications have been the biggest engine driving innovation and growth in the advanced polymer composites industry, Earth-bound applications—from car bodies to dental fillings—also abound. And here, on Earth, lies the greatest potential for commercial advance. Hunston says NBS wants to help industry to exploit this potential fully.

The Central NBS Program

"On a selective basis, and on a laboratory scale, we are coming at the problem from both ends—processing and performance," Hunston says. "We look at the chemical and physical properties of the constituent materials—the matrix resin and the particles or fibers—before processing. We monitor the curing processes associated with fabrication of composites at the molecular level and higher levels to find out exactly what's happening. Finally, we measure the performance of finished composites, all the way to failure. In all aspects of this work, we watch what happens to the material's microstructure."

In the NBS Boulder, Colo., laboratories, several researchers are looking independently at certain aspects of the polymer composites: how they are affected by exposure to radiation or extremely low temperatures and how the progress of internal



NBS researchers are developing methods for predicting how and to what extent the molecular networks of a thermoset polymer will be ordered, depending on its constituents and the processing variables. The graph above shows how closely data on network structure from an NBS neutron-scattering experiment follow the predicted curve. To acquire such data, researchers first label an epoxy monomer with deuterium atoms (top). Neutrons scattered off deuterium reveal the spatial position of the atoms of an average network. Ordered networks produce a scattering pattern with distinctive peaks; disordered networks produce a featureless background.

cracking, which researchers monitor by nondestructive means, relates to the material's ultimate failure. These efforts complement the studies being carried out by Hunston's group in the Polymers Division at NBS' Gaithersburg, Md., site.

His group is looking at both types of polymer composites: the high-performance thermosets in which the matrix material polymerizes during fabrication and the thermoplastics which are made from a matrix polymerized prior to fabrication. The reinforcing materials that become embedded in the matrix during the curing process—materials such as glass or graphite—may come in particle or fiber form, and the fibers can be long or short. In general, the longer the fiber, the stronger and stiffer the composite.

The researchers at NBS are monitoring the curing processes that take place in composites during fabrication to find out what changes occur in chemical, physical, and mechanical properties; how these changes relate to the performance of the finished product; and how the curing process can be controlled. They use six laboratory techniques to monitor changes during processing: Fourier-transform infrared spectroscopy for studying chemical reactions; dielectric spectroscopy, optical-wavegude fluorescence, and small-angle neutron scattering for studying molecular mobility; and dynamical-mechanical testing (shaking the material and using the internal movements to determine the relationship between applied stress and the resulting strain) and ultrasound for studying mechanical properties. Several of these techniques may be applicable, after further development, to commercial quality control or automation of manufacture.

The polymer composites group also wants to elucidate the behavior of polymer composites in use, relate that behavior to the properties of the constituent materials and the variables of the curing process, and develop mathematical models for predicting (and thus controlling) performance. Basic studies are being carried out in five general areas: 1) characterizing the constituent materials of a composite in terms of physical and mechanical properties and structure—both molecular structure and gross structure (voids and other defects); 2) relating the characteristics of the constituents to the curing process; 3) studying the interface between the matrix and the reinforcing material; 4) characterizing the properties of the finished composite; and 5) synthesizing experimental data into a predictive theoretical model.

Cooperative Research

As part of its research program, NBS is carrying out several cooperative projects. In one such effort with the Air Force, researchers at NBS are measuring the molecular properties of innovative new polymers that contain rod-like polymer molecules instead of long fibers. The Air Force wants to achieve the advantage of a short-fiber composite—specifically its ease of processing—without sacrificing the high performance of the long fibers. The main challenge is to get a homogeneous distribution of the rod-like molecules throughout the matrix material during processing, but the first hurdle is to develop a definitive technique for measuring their distribution. At the moment, nuclear magnetic resonance is the primary technique under consideration.

"...they have to acquire the theoretical and data bases needed to improve processing and to predict a material's performance and life expectancy."

NBS is studying delamination at the behest of several other federal agencies. Delamination is the failure of a polymer composite by the separation of its constituent layers, for one of two reasons:

cracks growing in the matrix that holds the layers together or cracks growing along a boundary of the matrix and the fiber material.

In one study for NASA, the Bureau is developing test methods to characterize resistance to delamination in composites. In a project for both NASA and the Navy, NBS researchers are looking for ways to prevent delamination by using thermoplastic resins or by toughening the matrix materials through the use of polymer additives such as rubber particles.

Several projects with the American Dental Association are aimed at developing and testing filled-polymer composites (resins reinforced with particles rather than fibers) as dental restorative materials.

Ideally, Hunston says, manufacturers might one day predict—and therefore control—the performance of a finished composite on the basis of the known properties of the "raw" materials and the control of variables in processing, such as temperature, pressure, humidity, and cure time. "It will never be quite that simple," Hunston admits, "but this technology can be brought under control.

"We are just scratching the surface in some of these areas," Hunston allows. "But we are making progress. We're on the way."

by Julianne Chappell
NBS Writer-Editor

Wanted: Industry Researchers to Join NBS Polymer Composites Program

Reply to: Dr. Leslie Smith
A305 Polymer Building
National Bureau of Standards
Gaithersburg, MD 20899
301/921-3734.

The time is ripe for manufacturers to join the NBS polymer composites program by sending their researchers to work with NBS scientists and engineers, says Dr. Leslie Smith, chief of the Polymers Division.

"Firms stand to gain a good deal by joining us at this time," he says. "They can get a head start in both basic knowledge and technical know-how."

Private companies can avail themselves of this opportunity through the NBS Research Associate Program. Under this program, researchers from industry, who are paid by their parent companies, have free access to NBS facilities and the benefit of collaborating with Bureau staff. Likewise, NBS programs are enriched by the expertise of outside researchers, and research results are made public.

The Bureau is actually taking the initiative in polymer composites research supporting commercial applications on behalf of industry. NBS is the only federal laboratory expressly empowered by Congress to use public resources for such a purpose. And it has done so in many areas over the last 85 years, with particularly notable success in materials research. Some U.S. industries—like optical glass—got their start in NBS laboratories. For many others, NBS has developed a solid foundation of data, measurement technology, and standards.

That foundation is what the young polymer composites industry lacks, according to Dr. Donald Hunston, head of the NBS polymer composites group. Providing this missing base involves long-term basic research and the development of test methods and Standard Reference Materials.* "The work is too far removed from product development for industry," he explains. Hence the need for NBS to take the initiative. But, as Hunston emphasizes, companies and universities are encouraged to take an active part in the NBS program and to help determine its direction.

"We have several researchers from universities working with us now," Hunston says. "We also have direct interactions with more than 30 companies and many universities through visits, seminars, and other forums, plus we exchange written information. NBS, NASA, and Hercules, Inc., have a formal cooperative arrangement for sharing materials and information and publishing together. Other companies, including Martin Marietta, B.F. Goodrich, and Texaco, participate in this arrangement on an informal basis."

* Standard Reference Materials are materials samples characterized and certified by NBS as to certain physical or chemical properties or composition. They are sold by the NBS Office of Standard Reference Materials to customers in science and industry for use in calibrating measurement systems. For more information, write or call the Office of Standard Reference Materials, B311 Chemistry Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-2045.

Searching for the More Vital Volt, the Apter Ampere

The more honest ohm....

They're the units used to measure electricity: the volt of potential, the ampere of current, the ohm of resistance, the farad of capacitance. You probably thought that somewhere there was someone who knew exactly how much each of those amounted to. After all, you get billed for the stuff (in kilowatt-hours, which involves volts, amps, and time.)

Not exactly. But there are people who have a very good idea how much. And they'd like to have an even better idea.

They work for the National Bureau of Standards. Many people think of measurement standards as something to be put in neat glass display cases, tended by employees in white lab coats carrying feather dusters. That's not the way it works at NBS, where "maintaining" measurement standards means keeping up with—and frequently creating—new advances in science and technology.

Standards of measurement are rather transient. The official meter this year, the basis for all length measurements in the United States, is not what it was 2 years ago, thanks in large part to research at NBS.

The Bureau goes to a great deal of time and trouble to improve the way we measure things. Nowhere is this more true than in the field of electrical measurements, where the most accurate standards possible are needed for applications ranging from basic physics research to the construction of sophisticated navigation and defense systems.

Electrical engineer Bruce Field (sitting) and physicist Marvin Cage use an automated system developed at NBS to monitor the quantum Hall resistance phenomenon against the electrical resistance standard maintained by NBS. The quantum Hall effect may become the basis for a new standard of electrical resistance based on fundamental neutral constants.

There are official definitions for these things, but they are not the sort that you can use every day. Take the ampere. By international agreement, its definition is in terms of the constant current flowing through two infinitely long, infinitely thin, parallel wires (in a vacuum) that would produce a certain amount of force per unit length between them. Practical problems make such a definition cumbersome to use every day.

...at NBS, ..."maintaining" measurement standards means keeping up with—and frequently creating—new advances in science and technology.

Instead, national standards laboratories like NBS develop ways to approximate the legal definitions of these units. The result is an "as-maintained" unit, which differs somewhat from the official definition. Just how much of a difference can be a difficult thing to measure. The typical (estimated) difference between an "as maintained" electricity unit at NBS and the international definition is in the neighborhood of a few parts per million (ppm). To put that in perspective, a ppm is about the difference 1 inch makes over the course of 16 miles.

" 'As-maintained units are a convenience," explains Dr. Bruce Field, an electrical engineer with the NBS Center for Basic Standards. "They are picked because they are stable—they don't change much with time—and they are easier to achieve than more basic measures.

"For example, at NBS the 'as-maintained' volt hasn't changed by as much as 0.1 ppm over the last 13 years. During that time, we've tried to measure that volt against the international definition to determine how far off it is. We think the difference may be about 9 ppm, but because of uncertainties in the values used in the definition, we only really know that it's somewhere between 7 and 11 ppm. We would say that the precision of the 'as-maintained' volt is about 100 times better than the accuracy with which we can implement the official definition."

Do It Yourself Standards

For the past few years, according to Field, the trend at NBS has been toward intrinsic standards for electricity. There are a lot of opinions about what constitutes an intrinsic standard. In general, says Field, it's a standard that relies on nothing but some very fundamental properties like the basic constants of nature (such as the speed of light). A device that can measure some quantity directly in terms of its internationally agreed-on definition is also considered an intrinsic standard.

In any event, an intrinsic standard definitely does not depend on some particular, unique object. The great thing about intrinsic standards is that there can be so many of them, and all the same. Between 1910 and 1972, the volt, as far as the United States was concerned, was measured in terms of a set of wet electrochemical cells kept at NBS. If you wanted to calibrate something in terms of the U.S. volt, your device (and sometimes you) travelled to NBS.

In 1972, NBS converted to an intrinsic standard for the volt—the Josephson junction, based on the Josephson effect. The Josephson effect is an elegant physical phenomenon. You start with a comparatively simple superconductor device, made much the same way integrated circuits are. You put in an electrical current at a very accurately known frequency, and the device produces a constant voltage which you can calculate very accurately from the frequency and the ratio between two constants of nature (the charge on an electron [e] and Planck's constant [h]).

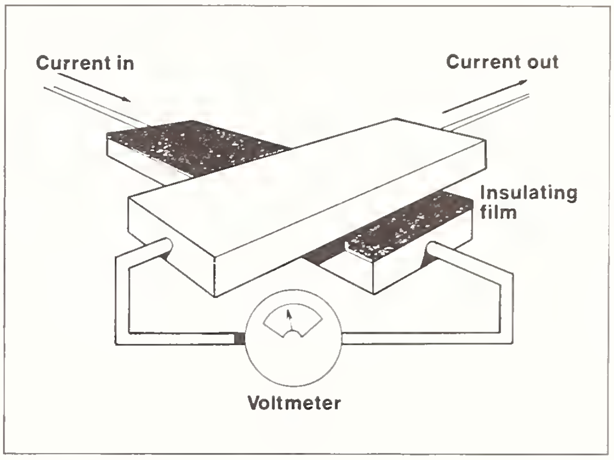
You can get the same standard wherever you have access to accurate frequencies, which is almost anywhere in the world. This makes the volt standard a lot more portable, and the new standard is more stable as well.

"Anytime you find a new standard with improved stability," says Field, "you can improve the accuracy of your measurements, even with the old standard. Before we had the Josephson effect, we had to maintain the volt with a collection of electrochemical cells—at one time, as many as 44. The only way to test their stability was to measure them against each other and try to make corrections. After we started making measurements against the more stable Josephson effect, we discovered that the set as a whole had been drifting down in value ever so slightly."

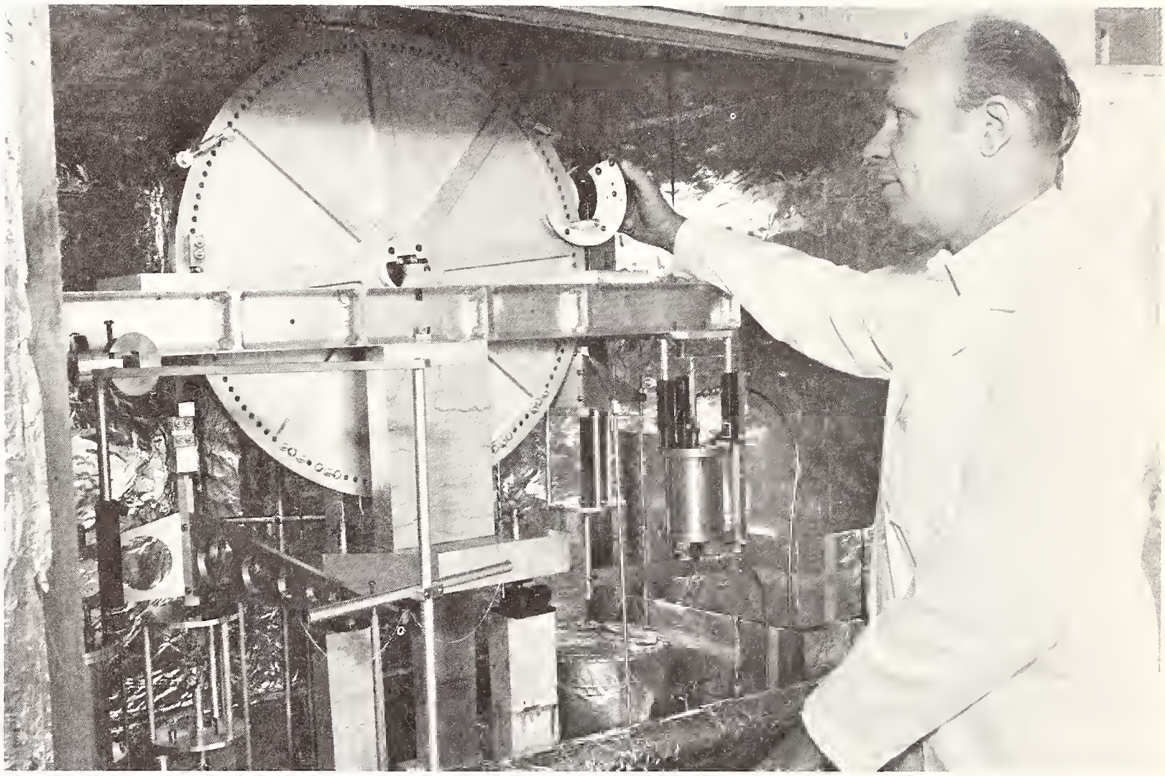
The discovery of intrinsic standards like the Josephson junction is nice, but rare and difficult to predict. The Josephson effect appeared on the physics scene quite unexpectedly in the 1960's, the work of a very talented British graduate student.

In 1980, something similar happened to the standard for electrical resistance, the ohm. A German researcher, von Klitzing, showed that a particular resistance, called the "Hall resistance," generated by a current flowing in a semiconductor, could be calculated under special circumstances in terms of our old friends h and e, or equivalently, in terms of another string of basic constants: the speed of light, the electromagnetic permeability of a vacuum, and the "fine structure constant," which has to do with the energy levels of electrons in an atom.

Since 1930, the NBS standard for resistance has depended on a set of 10 standard resistors. NBS researchers, in common with measurement specialists around the world, seized on von Klitzing's phenomenon—now called the "quantized Hall effect"—as a new opportunity for an intrinsic standard and by 1983 had developed it to a sufficient degree that



Shown is the a.c. Josephson effect, as used in maintaining the constancy of the U.S. legal volt. Microwaves of fixed, accurately known frequency irradiate the junction of two superconductors (the temperature is near absolute zero) separated by a thin nonconducting film. If the current is increased steadily from zero, voltage remains zero until a critical current, when the voltage jumps to $\triangle$v, a small value determined by the microwave frequency. At a somewhat greater current, the voltage rises suddenly to 2·$\triangle$v, and so on—rising in a series of equal steps. At any point, the voltage is some whole number times $\triangle$v. By setting the current so that it is in the range where the voltage is some specified multiple, n·$\triangle$v, we always obtain the same voltage, to a high degree of precision. This voltage is then compared with the voltages of NBS standard cells.



Above is the advanced current balance used in NBS experiments to determine the value of the ampere. Researcher P. Thomas Olsen adjusts the balance wheel of the instrument, which is housed in a foil-lined box to reduce external influences. The coils carrying the electrical current during the experiments are in the room immediately below the balance mechanism.

it could be used to check the stability of the NBS ohm and eliminate a drift in the standard of about 5 parts in 100 million per year.

What's in Store?

Today, NBS researchers are at work on a variety of fronts to keep the nation's electrical standards at "the state of the art."

The Josephson junction is an excellent standard, but it produces extremely low levels of voltage (around 5 thousandths of a volt at best), at least for practical purposes. National standards laboratories use collections of Josephson junctions, from a couple up to about 20, each with its own source of current and each individually "biased" (sort of like tuning). They are hooked up in series to raise the total voltage of the standard. But even that leaves you far below the 1-volt level where most calibrations have to be performed.

Researchers at the NBS Boulder, Colo., laboratories, working with colleagues from the West German national standards laboratory, have developed ways to produce up to 1,500 Josephson junctions linked on a single integrated-circuit chip that can

"Intrinsic standards offer the possibility that anyone who wants one can have a standard for voltage or resistance or whatever that is equivalent to the national standard right there in their plant."

produce reliable 1-volt voltage standards. They now are running tests on the stability and accuracy of their handiwork, with hopes of having it become the U.S. standard for voltage in about a year.

The quantized Hall effect is still so new that, according to Field, "we don't yet completely understand why the effect works." NBS research has shown that as long as the Hall effect device is kept

What's a Microvolt Here or There?

Electrical standards at 1 part in 10 million.

Who needs that sort of accuracy? One of the major consumers of electrical measurements at the ultimate levels reached by the National Bureau of Standards are research physicists, particularly those interested in such arcana as the theory of quantum electrodynamics (QED).

QED, one of the basic theories of modern physics, describes the fundamental behavior of electromagnetism on an atomic scale. It is perhaps the most successful scientific theory in history, since experiments to verify the predictions of QED have found no discrepancies even when pushed to limits of modern technology.

Interestingly, it turns out that both our ability to make predictions based on QED theory and our ability to test those predictions depend to a surprising extent on extremely accurate values for the basic electrical units. Thus experiments on the quantized Hall effect, for example, serve not only to refine our standard for electrical resistance but also to refine our understanding of the basic mechanisms of the universe.

Improvements to the electrical standards maintained by NBS also have an ultimate effect on more prosaic customers. The best available accuracy for instruments used "in the field" depends on the best available accuracy at the laboratory that sets the standards, even if the field instruments generally operate at a level far below that of a standards lab.

The best digital multimeters of today, basic tools for electronics engineers, operate at levels of precision and accuracy that would have been impossible to test without improvements in the NBS standards over the last few years.

Intrinsic electrical standards are even more important because they offer users the possibility of on-the-spot electrical standards at the same level of accuracy as those at NBS.

Military systems designers, for example, could conceivably use on-board Josephson junctions to keep inertial navigation systems at the necessary levels of accuracy.

cold enough—it functions within a degree of absolute 0—the effect is independent of the actual device being used, but there are still some unknowns in the process.

NBS researchers are studying the behavior of quantized Hall devices made from different materials to learn if there are any unexpected differences in the devices' behavior and to determine how stable the devices are over time.

They also are doing an experiment to measure the official value of the farad, the unit of electrical capacitance. This can be done to about 0.05 ppm, and given a value for the farad and a standard frequency, you can get a value for the international ohm that can be compared with the Hall resistance standard. The process takes a couple of years to complete, which helps to explain why such experiments are run only about once in a decade.

As a practical, day-to-day matter, with a working standard for the volt and one for the ohm, you can calculate the value of the ampere. However, NBS scientists are working on two different methods for measuring the international ampere. At the moment that value is known to little better than 10 ppm, but the Bureau hopes to push that to 0.1 ppm.

In a way, NBS is hard at work putting itself out of the electrical standards business. As Dr. Barry Taylor, who supervises the research in this area at the NBS labs in Gaithersburg, Md., explains, "Right now our measurement system is a hierarchy. NBS calibrates standards for primary laboratories, they calibrate standards for secondary labs, and so on down the chain. Each step costs you something in accuracy. But as some industries, particularly in electronics, require better and better accuracy in their measurements, you may have to improve the system by eliminating some or all of the middlemen.

"Intrinsic standards offer the possibility that anyone who wants one can have a standard for voltage or resistance or whatever that is equivalent to the national standard right there in their plant. You could do away with the old concept of calibration chains. Conceivably you could remove the need for a National Bureau of Standards, at least for electrical calibrations."

by Michael Baum
NBS Public Affairs Specialist

Evaluating Volts, Jolts, and Lightning Bolts:

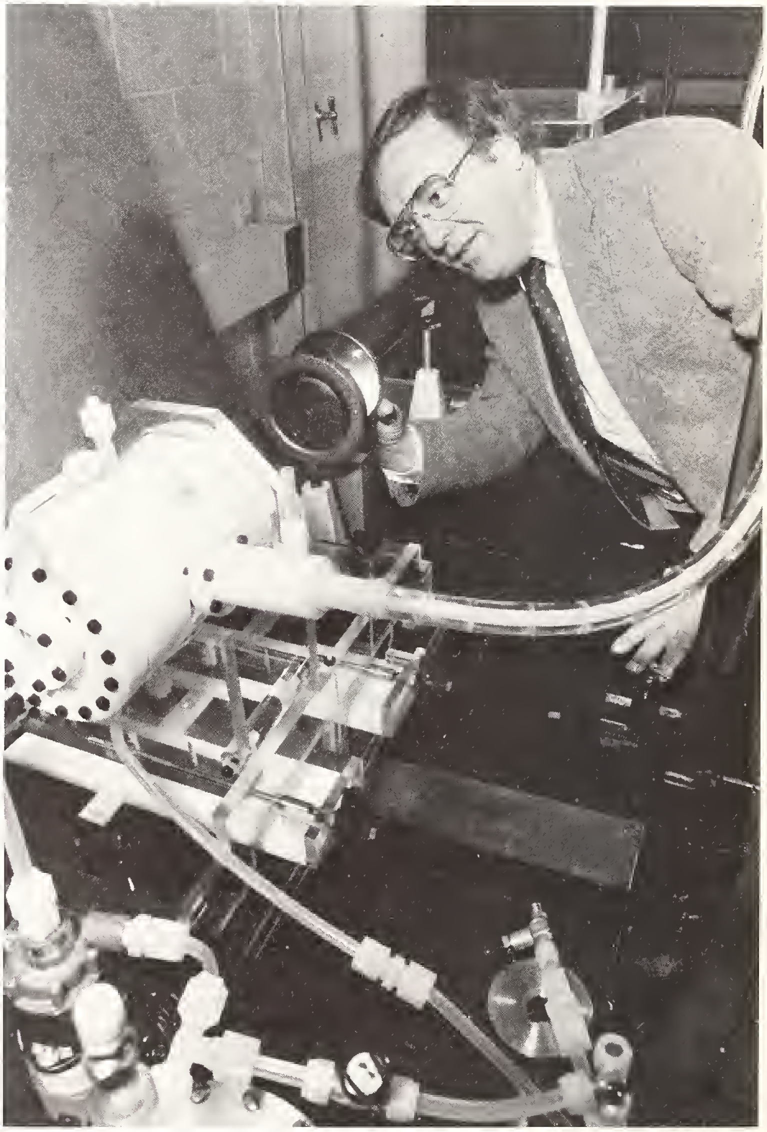
All in a Day's Work at NBS

We are all familiar with the annoyance of electrical power blackouts. Lights flicker and die. The TV quits. And the family makes a mad dash for candles and flashlights. More importantly, vital services such as traffic control and residential heating are disrupted. Often, lightning is the culprit.

For most of us, lightning is a dangerous and frightening phenomenon, as well as the cause of occasional inconveniences. But researchers at the National Bureau of Standards are using lightning-like pulses as a high-tech tool to help utilities and manufacturers define how well their equipment will hold up if struck by lightning.

Such predictions require an extremely accurate and reliable system of measurement, something that is an NBS specialty. Here, researchers are working for and with industry, universities, and other government agencies in a newly expanded high-voltage measurement facility. They tackle problems ranging from lightning bolts to fluctuating currents in machines used to weld metal shipping containers. In each case, NBS performs a special measurement service unlike that of other electrical measurement laboratories around the country.

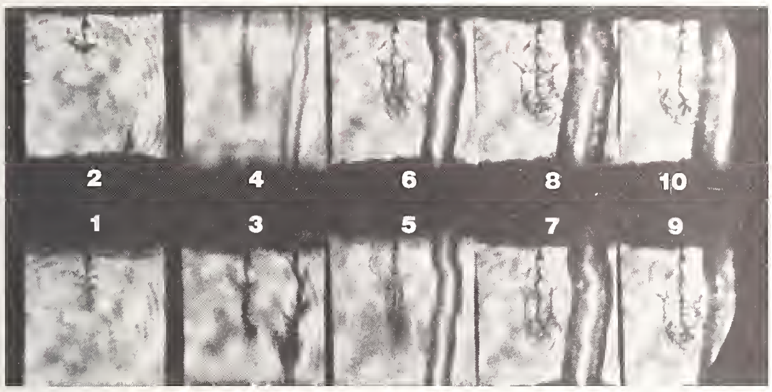
Take lightning for example. To evaluate the response of power equipment when it is hit by lightning, private laboratories routinely create simulated versions of lightning bolts—pulses that last only a few millionths of a second (microseconds). But since the instruments needed to measure these "bolts" would be destroyed by such high voltages, the laboratories use a voltage divider to reduce the simulated lightning to a few hundred volts. NBS gets into the act because utility test operators need to know how the dividers will respond to high voltages before they can be used.



Dr. Robert Hebner adjusts a unique NBS device that optically measures electrical fields and space charges in high-voltage insulating systems.

Because NBS is one of the few places in the world where voltage dividers can be specially calibrated, utilities, manufacturers, and other laboratories turn to the Bureau for these very accurate measurements. With an accurate measurement base traced to NBS, the effect of lightning on utility equipment could possibly be predicted before a disastrous blackout occurs.

The Bureau facility also is being put to use for examining the phenomenon known as "breakdown." While that word may prompt the image of a car stalled helplessly by the side of the road, NBS researchers know "breakdown" as another curse they are



This dramatic series of high-speed motion picture images shows how an insulating oil can break down in a transformer at a power substation. Each frame represents 10 billionths of a second. In frame 1, an anchor-shaped lightning bolt begins at the upper (negative) electrode. Frame 2 shows the beginning of another bolt from the lower (positive) electrode. By frame 3, the bolt has made contact from positive to negative, and in the remaining frames, the characteristic lightning is formed. The dark cylinder surrounding the bolt is the shock wave or thunder.

helping the electric utility business to investigate: the sudden failure of an insulator to insulate.

Such a failure could cause damage at a power plant or substation, which would require expensive repairs and leave perhaps hundreds of thousands of customers without electricity. Thus utility companies, and agencies that regulate them, are interested in reliable measurements of just how well an insulator can do its job.

At NBS, amid a bank of controls, monitors, and test devices, researchers work out highly specialized measurement standards that permit utilities and other laboratories to test with confidence insulators, electrical outlets, lightning arresters, and even citizens-band antennas. Since NBS is not a regulatory agency, Bureau researchers develop the test methods, then turn the results over to others, who often adopt these test methods as voluntary, private sector standards.

To study insulating materials, which may be solids (paper, for example), liquids (oil), gases (air), or combinations of these (oil and paper are used in many transformers), NBS researchers connected them to a huge machine with rows of softball-sized electrodes. Called a standard lightning generator, this machine can energize an insulating material with as much as one-half million volts. The idea is to create a transient voltage, which simulates what might happen to the insulator if the substation were subjected to rapid increases in voltage or struck by a bolt of lightning. With specialized instruments, NBS researchers measure the effectiveness of the insulator and evaluate the accuracy of test equipment used by the utility companies.

Utilities have become especially interested in the performance of gas insulators in recent years because of the many gas-insulated substations that have been built nationwide. These facilities use a gas, such as sulfur hexafluoride, to insulate transformers, high-voltage cables, and switches. Though the substations are compact and fairly inexpensive to build, breakdown is of particular concern because ideal conditions are present for the transient voltages that prompt failure.

To study these gas insulators, NBS uses a nanosecond (billionth of a second) transmission line—a long, tubular device that allows transient voltage signals and their effects to be observed in a controlled situation. NBS researchers and utility representatives expect this research to lead to more effective insulators as well as to a better understanding of the conditions under which existing insulators will perform more reliably.

Though utilities and other industries often use the NBS facility, the Bureau has many of its

In each case, NBS performs a special measurement service unlike that of any other electrical measurement laboratories around the country.

own projects which aim to improve the science of voltage and current measurements. In one such study, NBS researchers are comparing voltage and current measurements made with conventional equipment to those produced with newer electro-optical and magneto-optical devices. They also are investigating how well standard voltage and current measurements can be simulated on a computer. Such computer modeling could save both time and money.

A laboratory like the Bureau's, with its variety of equipment and experienced staff, is a boon to many industries, universities, and other federal agencies. "We have a lot of demand from industry to accept guest workers because they need a facility of this kind to do their work," says Dr. Robert E. Hebner, who manages the facility in the NBS Center for Electronics and Electrical Engineering.

One such client, the Exxon Research and Engineering Company (ER&E), is studying electrical breakdown in the oils used as insulators in transformers. With an elaborate high-speed photography system that runs at a speed equivalent to 20 million frames per second, researchers are making accurate measurements of precisely when breakdown occurs after a voltage is applied to the oils under study. "NBS has the specialized equipment we need for our work," says Eric Forster, a scientific adviser for ER&E who has collaborated with NBS for 5 years. Forster adds that by joining forces, NBS and ER&E have produced research results that have put both organizations in the forefront of technology in solving complex problems encountered in the electrical industry. In what he terms "an ideal marriage," Forster says the NBS/ER&E program helps both parties because it pairs the Bureau's interest in measurement science with ER&E's interests in understanding the properties of hydrocarbon liquids.

While much of the Bureau's work at the facility is in determining voltage, there is also a need for reliable measurements of current. For example, Sandia National Laboratories in Albuquerque, N.M., has turned to NBS for help in improving quality control for large industrial welding machines, which typically draw 100,000 amperes of high-pulsed current. (At its peak, this current level is equivalent to that drawn by 1,000 homes.) But in order for welds to be consistent, current must also be constant. Sandia needs to know if its test equipment is giving accurate current measurements so the welding machines can produce the repeatable welds needed for sealing metal container plates. The New Mexico laboratory has asked the Bureau to evaluate measurements made by its test equipment under simulated conditions in the NBS lab, as well as to suggest how to make the current more consistent.

NBS researchers and utility representatives expect this research to lead to more effective insulators as well as to a better understanding of the conditions under which existing insulators will perform more reliably.

The accuracy of test equipment also has been a problem for electric utilities that make measurements of various aspects of direct current power lines. There has been interest in such measurements in recent years because of concern about the possible health effects of dc transmission lines. But, as Hebner says, utilities "have bought test equipment that sometimes gives inaccurate measurement readings." To evaluate the accuracy of such equipment, NBS has set up a scaled-down version of a typical dc power line. Instruments under study are electric field meters, Wilson plates (for measuring current), and ion counters. The latter instruments, which measure the ion density in air, have become important for their role in studying the biological effects of ions, as well as for industries, such as semiconductor manufacturers, which are interested in manipulating ion density in clean rooms to control static electricity.

Recently, the NBS facility also has been used to help the Consumer Product Safety Commission determine what might happen if a home-based citizens-band antenna were to fall on a power line. And the Rural Electrification Administration has used the facility to measure how much current a telephone cable can take before melting and causing a fire hazard.

More companies, universities, and federal agencies have lined up to use the NBS facility in between the Bureau's own projects. That's because while there are other electrical testing facilities in the United States, the NBS laboratory is the only one exploring the fundamentals of electrical measurements—fundamentals that other labs ultimately use as standards. As Hebner says: "We're the ones who are in the business of worrying about how well the measurements can be made."

To discuss the possibility of cooperative work or the availability of the high-voltage facility, write or call Dr. Robert E. Hebner, B344 Metrology Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-3121.

by John Henkel
NBS Public Affairs Specialist

NBS Fire Research is Framework for Safer Buildings

For years, architects, engineers, and code officials have been in somewhat of a dilemma. How do they ensure that buildings that are functional and attractive are also safe from the threat of fire? Traditionally, architects and engineers have used their expert judgment, within the bounds established by local officials who set and enforce strict codes that often dictate choice of materials, building design, and safety features. Likewise, these officials' decisions are made on the basis of their experience and judgment.

Researchers at the National Bureau of Standards' Center for Fire Research, however, are helping to resolve that dilemma. In recent years, their studies have resulted in new knowledge of how fire grows and spreads, new tests to determine the safety of furniture and furnishings, and new methods to evaluate the fire safety of a room or building. Little by little, these achievements have added flexibility to building design and retrofit.

In particular, the Bureau's scientists and engineers have brought fire research into the computer age. New mathematical models have been developed that enable NBS researchers to predict how furniture will behave in a fire, to estimate how long it takes people to get out of a burning building, and to assess alternative ways to achieve different levels of safety. In turn, architects and engineers can use these models to produce fire-safe computerized designs.

For researchers, computer modeling has at least one distinct advantage: Once developed, it is cheap. A computer test often costs $100 or less. A full-scale room burn, by comparison, can cost up to $20,000 and averages $10,000. Even a laboratory-scale test can cost $5,000 and take a week to set up. Further, each test reproduces only one fire situation. In the laboratory, it is impossible to test every size and shape—let alone all potential contents—of a room or building.

Mathematical models allow researchers and designers to use what is known about fires to predict what would happen if a particular fire were to break out in different-sized rooms or buildings or under different conditions. A fast, reliable computer model just completed by Bureau researchers can predict the spread of fire, smoke, and toxic gases throughout a structure. Smoke and toxic gases that are produced when materials burn are of particular concern since 80 percent of the people who die in fires succumb to smoke and gas rather than to flames or heat.

Called "FAST," the model predicts the buildup of fire in a room or other compartment, such as on a ship. It also shows how the smoke and toxic gases will move from one room to another, how quickly they move, and their concentrations in different areas.

"The model incorporates the same chemistry and physics as other models do, but it is considerably faster and much more 'robust,' " says Dr. Walter Jones, a Bureau scientist. "In other words, it can complete calculations where some programs would run and run and not come up with an answer."

FAST is designed to be used by building and product managers, fire safety experts, and regulatory officials in state and local governments. Written in ANSI Fortran, FAST can run on mainframe and minicomputers, and

Researcher Walter Jones is developing sophisticated computer models designed to predict smoke and toxic gas movement throughout a building.

Here physical scientist Randall Lawson adjusts instrumentation on the Bureau's furniture calorimeter, part of an NBS-developed method to measure the rate at which heat is released by burning furnishings. The heat release rate in large part determines how a material will contribute to a room fire.

the NBS researchers are experimenting with it on a microcomputer.

Says Jones, "Anyone who is moderately knowledgeable about computer modeling can use FAST. Initially it will probably be used by some of the bigger fire protection engineering firms and architectural firms which now use modeling to solve problems. But it will catch on as others, including firefighters and code officials, become familiar with the technology."

To help broaden the use of FAST and other fire models, NBS is setting up a fire simulation laboratory to demonstrate the fire and smoke models in a variety of applications. Workshops are expected to begin this fall.

In research aimed at improving the fire safety of existing buildings, the Bureau has devised a system that allows architects, engineers, researchers, and code officials to assess alternatives for reaching the level of safety required for and provided by some specific types of public buildings according to the National Fire Protection Association's (NFPA) Life Safety Code. The Life Safety Code is used by many state and local jurisdictions in their building and fire codes. NBS' system, known as the Fire Safety Evaluation System (FSES), awards points for a building's fire safety features and subtracts them for missing features or unsafe conditions. Through the use of the FSES, a building can meet the code by having combinations of fire safety features other than the fixed requirements in the code as long as equivalent safety is provided.

The Fire Safety Evaluation System was designed originally to upgrade fire safety and reduce fire protection costs in hospitals and other health care facilities. For new hospitals, the solution is relatively easy: Safety features are simply incorporated into the building's design. But for older hospitals, adding stairways to eliminate dead-end corridors, for example, could cost millions of dollars.

In one case the FSES was used to evaluate a major hospital complex, an older facility facing massive renovations to meet fire safety codes. The FSES approach allowed the hospital to choose a fire safety system involving judicious use of smoke detectors, smoke barriers, and some sprinklers, among other improvements, to give code equivalency. The estimated cost of the FSES changes was $4-6 million compared with previous estimates that ranged from $8-40 million, and the hospital was able to choose an approach that did not interrupt medical services.

Published in 1978 and included as an appendix to the 1981 NFPA Life Safety Code, the Fire Safety Evaluation System has recently been modified for use with board and care homes. In the United States, these dwellings house an estimated 2 million residents who are elderly, physically handicapped, or developmentally disabled.

NBS researchers developed a set of requirements that categorizes homes as either large or small, depending on the number of residents, and ranks them by ease of escape from a fire. The more people in a home and the more time needed to evacuate it, the more safety features would be required.

Says Harold Nelson, head of fire safety performance at NBS, "The goal is to upgrade fire safety, decrease building or retrofit costs, and at the same time permit quarters that are as homelike as possible."

The Veterans Administration is now using the system, while the state of Colorado has been using it for over a year to evaluate the safety of small board and care homes housing mentally retarded and developmentally disabled residents. And the city of Topeka, Kan., is using part of the system in connection with its own housing codes. Published in March 1983, the FSES for board and care homes has been incorporated in an appendix to the 1985 revision of NFPA's Life Safety Code.

At the request of the National Institute of Justice, a third FSES has been developed for prisons and jails. It acknowledges cell doors that can be opened automatically by at least two different methods and the use of fire doors to divide corridors and prevent fire spread. The FSES for prisons and jails was evaluated at 30 institutions and was subsequently published as an appendix to NFPA's 1985 Life Safety Code.

"Our job is to develop and bring together the various fire research techniques to ensure that everybody involved in fire safety is using the best available technical framework for making decisions."

But not all research at the National Bureau of Standards is done on computers. Fire researchers also use laboratory studies to investigate how smoke spreads, how different materials burn, and how effectively sprinklers control fires.

"Our job is to develop and bring together the various fire research techniques to ensure that everybody involved in fire safety is using the best available technical framework for making decisions," says Dr. Jack Snell, director of the NBS Center for Fire Research. (As the nation's central fire research laboratory, NBS conducts research for a number of federal agencies and sponsors most of the academic research on fire done in this country.)

"To do that, we all have to operate from the same set of figures," Snell adds. "The figures could result from a standard test, a computer model, or anything in-between. But they had better be accurate, available, and applicable. That is the goal of good, broad-based research."

Toward that end, as a non-regulatory research laboratory, NBS has developed new techniques and tools for measuring how much heat is emitted when materials, or even whole pieces of furniture, burn. Such measurements are vital in determining how a fire might grow and spread, and thus what safety requirements should be considered for furniture and materials and what additional safety is provided by smoke control fans or sprinklers.

In one Bureau lab, a small piece of rayon-and-polyester-covered foam sits atop a metal stand ready to be burned. Once ignited, a fan above the stand pulls hot gases and soot from the flaming material into ducts connected to a machine. The machine contains sensitive instruments that measure how much oxygen the hot gases contain and compare that with the amount normally in air.

Scientists use data from the assembly, called a cone calorimeter, to calculate the rate of heat release, which increases with the amount of oxygen used. The rate of heat release tells whether a material will burn slowly, or so quickly that it will ignite other furniture, carpeting, or bedding in the same room. The latter scenario could lead to flashover, that point when fire suddenly spreads from the initial burning object to an entire room, engulfing it in flames.

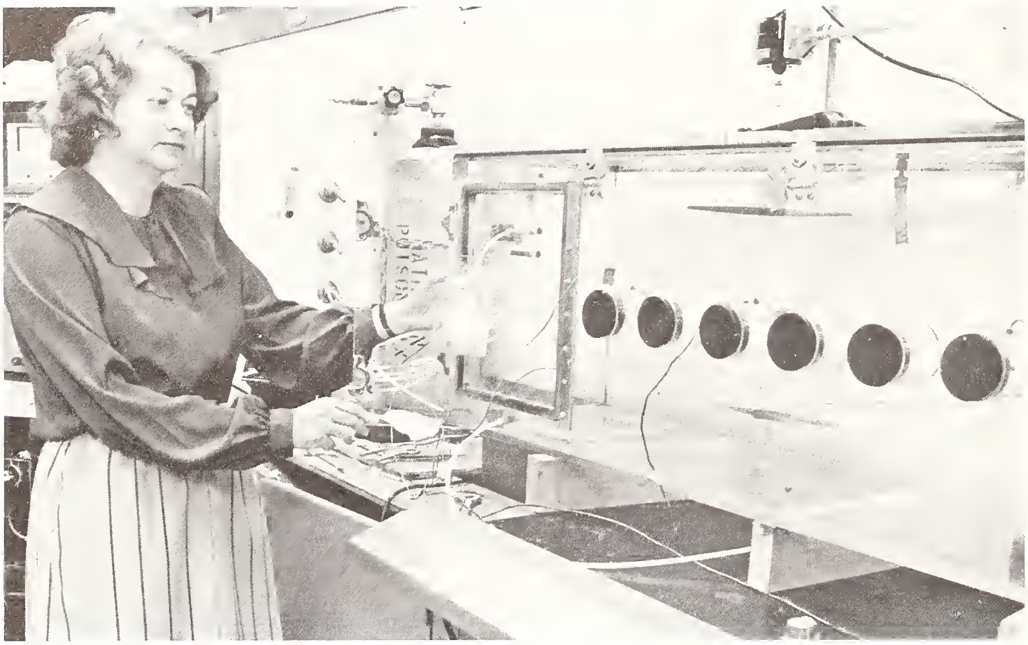
"Rate of heat release is the single most important factor in a building fire," says Vytenis Babrauskas, an NBS fire researcher. "That is what is meant when someone asks, 'How big is the fire?' "

Under development at the Bureau since 1978, the cone calorimeter is now being considered by ASTM as a standard test method.

In an extension of the same concept, Babrauskas and his NBS colleagues have developed a furniture calorimeter. Like the cone calorimeter, it measures how much oxygen is used when furniture burns as a way of knowing the rate of heat release. In this case, however, whole sofas, chairs, desks, and other furniture items can be tested rather than just small samples of materials.

Babrauskas has recently developed a set of rules with which researchers can predict the peak rate-of-heat-release values of the furniture calorimeter from cone calorimeter data. So now these small-scale, inexpensive cone calorimeter measurements can be used to estimate what will happen to individual pieces of furniture in a fire. From this work, NBS researchers are developing broader predictions of the rate of heat release, and they also plan to determine the rates at which soot and toxic gas are produced. They are now cataloging the fire properties of different materials and furniture items using the cone and furniture calorimeters.

Somewhat earlier the Bureau developed a special test to determine the extent to which carpeting and other floor materials will spread a fire. Previously, scientists and code officials had to rely on the Steiner tunnel test, which was designed for wall and ceiling materials, but not for carpets. Some carpets, rugs, and



Barbara Levin, research biologist, prepares an experiment aimed at establishing in a measurable way the relative contribution of smoke toxicity to the overall hazards of fire.

pads rated well on the Steiner tunnel test for flammability, only to propagate fire rapidly when in a corridor near a burning room. The reason: Flames and hot gases passing down the corridor radiate energy, often raising the temperature of the flooring materials enough to allow flames to travel rapidly.

This test apparatus, called the flooring radiant energy panel test, is used to judge how much radiant energy is needed to cause a hazard with different flooring materials. It offers a way to select materials to prevent a room fire from spreading to a hall or corridor. Originally developed for hospitals and other health care facilities, it was adopted by the Department of Health, Education and Welfare (now the Department of Health and Human Services) in 1977. The National Fire Protection Association added the test to its Life Safety Code in 1981. It is now used to test attic insulation products, too.

It is important to know how materials burn, but we also need to understand more about the smoke and gases produced when they burn. The vast majority of fire deaths are due to the inhalation of smoke or hot gases. Although carbon monoxide, a combustion product of most burning materials, has been widely considered as the primary cause of these deaths, laboratory tests and analyses of some fire victims have suggested that other toxicants or factors may contribute to some deaths. Product manufacturers, building officials, and others who want to know more about the toxicity of the combustion products of various materials have been handicapped by the lack of an agreed upon laboratory test.

NBS fire researchers developed and published a measurement method that product manufacturers and materials researchers can use to assess the acute inhalation toxicity of materials when they burn. The test, primarily intended for research and preliminary product screening purposes, was developed in cooperation with representatives from industry, universities, and other government agencies. According to Dr. Richard Gann, chief of the Fire Measurement and Research Division, the test involves heating a sample of a material in a special furnace and exposing test animals (rats) to the combustion products. The materials are tested under both flaming and smoldering conditions to reflect two major modes of material decomposition in fires.

"We are now learning the extent to which the data from this device can also be used in fire hazard models," says Gann. "To this end, we are comparing the data with those from another research apparatus in which the same materials are burned under a wider range of fire conditions. If successful, the values from the toxicity measurement method can be combined with other materials, fire, and building data to evaluate the materials' total contribution to fire hazard."

"What we are trying to do in all of our research," declares Snell, "is to make buildings truly safe for people and at the same time reduce fire protection costs. By combining our laboratory results with computer analyses, we should be able to reduce the dilemmas faced by architects and building officials in the past."

The Making of the Advanced Heat Pump:

Research to Influence the Marketplace

Nearly 30 percent of all new houses come equipped with heat pumps for heating and cooling. Before the year 2000, heat pump sales may reach 2 million units per year in the United States alone. At that time, the American home is expected to consume 33 percent of the electric power sold by utilities.

The Electric Power Research Institute (EPRI), the electric power industry's research organization, wants the power demand of those 2 million heat pumps to dovetail as efficiently as possible with the power supply, thus saving the utilities and their customers money. To that end, EPRI is funding a number of heat pump research and development projects with manufacturers, research organizations, universities, utilities, and others.

These include a $4.7-million cost-shared project with the Carrier Corporation to develop an advanced heat pump for homes and small businesses.

EPRI has contracted with the National Bureau of Standards for research related to the EPRI/Carrier program. NBS is analyzing the economic effects of alternative advanced designs on both the utilities and the homeowner.

How heat pumps affect a particular utility company depends on many factors, as James M. Calm of EPRI points out. Calm is EPRI's project manager for heat pump development. "It is important to remember that the electrical industry is not homogeneous," he says. "Utility companies differ in the kinds of generating equipment and fuels they use, the amount of reserve capacity they can control, and the way the power demand [load] is distributed on a daily or seasonal basis. Such variables greatly influence the costs of providing electricity now and in the future."

Virtually all utilities have summer and winter "peaks"—periods when electrical demand increases sharply to meet air-conditioning and heating requirements. More than 70 percent of utilities have higher summer than winter peaks, however, and the trend is in this direction. In general, most utilities resort to expensive alternatives to meet these peaks. They buy power from another source, for example, or run "peaking" generators to supplement the power supply. No one combination of heat pump design features would be optimal for every single utility company, but EPRI has identified general heat pump development goals that would best benefit customers and the industry as a whole.

"EPRI's goals are very clear," says Stephen Petersen, an economist in the NBS Center for Applied Mathematics. Petersen is conducting an economic analysis of advanced heat pumps for EPRI. "When Jim Calm first approached me about this research, he said they were after dramatic improvements in performance but wanted to avoid developing an unmarketable product." The initial goals set in 1981, subject to revision if necessary to insure commercial success, were these: a 30-percent improvement in seasonal heating performance over the best available equipment, a 2-kilowatt reduction in peak power demand per residence during the heating season, and summertime energy efficiency equal to the best performing air-conditioning unit then on the market.

"But there's a rub," Petersen says, and it explains why manufacturers are not already producing advanced heat pumps. "The performance goals can be met with known technology, but the cost of doing so will raise the purchase price of a heat pump significantly."

Petersen, with advice from Glendon Raymond, head of the advanced heat pump project at Carrier, went in search of the right mix of design goals that would make a heat pump "advanced," by EPRI's standards, and economical as well. Petersen developed computer models based on an earlier NBS/Department of Energy model of heat pump performance. He factored in data and projections from EPRI and Carrier, and drew on expertise developed at NBS over the past 10 years in engineering economics and energy use in buildings.

He then calculated the effects of alternative advanced heat pump designs—on an hour-by-hour basis over an entire year—on representative utilities typical of those in various regions in the United States. He weighed that information with data on the economic consequences to consumers who would pay to own, operate, and maintain the advanced heat pump over its lifetime.

NBS is analyzing the economic effects of alternative advanced designs [of heat pumps] on both the utilities and the homeowner.

His findings spell good news for utility companies and consumers alike. It is possible, says Petersen,

By using computer modeling, economist Stephen Petersen is helping EPRI find the right mix of design goals that will make a heat pump "advanced" and economical.

to achieve most of the performance improvements important to EPRI and still have a commercially competitive product.

One important approach is to integrate heating and cooling with water heating and by doing so reduce the total amount of electricity required for these operations. Waste heat from air conditioning can heat water—and thus save energy—in summer. A heat pump's excess capacity can do likewise in the winter. (The full heating capacity of a heat pump is seldom needed to keep a building warm, except during severe cold.)

Petersen also emphasizes four ways of increasing the overall efficiency of a heat pump: 1) improve steady-state efficiency; 2) make output vary with load; 3) increase low-temperature heating capacity; and 4) use fossil fuel rather than an electric furnace for auxiliary heating.

Improvements in steady-state efficiency, which can be achieved with more efficient motors and compressors and enlarged heat-transfer surfaces, provide significant improvement in cooling performance. However, in the heating mode, the feature with the greatest potential for energy savings is an adjustable-speed compressor.

Today's heat pumps are generally driven by single-speed compressors: Output (capacity, expressed in Btu/hr) is fixed, and these compressors cycle on and off to meet changing loads, which reduces efficiency.

An adjustable-speed compressor would match the heat pump's output to the heating or cooling load. Output would vary in tandem with changes in load, avoiding inefficient on/off cycling. An advanced heat pump would consume maximum power only if conditions warranted maximum output. And there is one further advantage: An adjustable compressor can boost the heating capacity of a heat pump at low temperatures significantly above that of an otherwise identical single-speed system.

Because it permits heat pump capacity to increase without wasting power, the adjustable capacity compressor would also decrease the use of the auxiliary heat source, usually an electric furnace, thus reducing heating peak demands.

Raymond, of Carrier Corporation, says his company hopes to have a prototype advanced heat pump ready for production by 1988. EPRI, meanwhile, is already pursuing advanced heat pump concepts for applications other than homes and small businesses. In addition, the institute is planning projects to "advance" heat pumps even further in the future. EPRI's Calm expects to use the NBS model in setting and justifying heat pump performance goals on which these projects will be based.

Petersen, at NBS, is looking at what electric utilities might do to get buyers interested in the EPRI/Carrier advanced heat pump. "If you consider the costs of buying, operating, and maintaining an advanced heat pump over its lifetime, with water heating included, it is competitive with today's heat pumps," Petersen says, "even though its price tag is going to be higher."

However, he thinks many buyers, confronted with that higher initial cost, will need some additional incentive before they buy. As part of the EPRI/NBS agreement, Petersen is preparing documentation on the computer program he developed for analyzing heat pump performance. With this program, a utility company will be able to calculate the impact of a specific advanced heat pump on its operation. The company can then determine what basis it might have for transferring resulting savings to consumers—in the form of rebates or other incentives that would make the advanced heat pump an especially good buy.

Calm sees broader uses for Petersen's research. "Steve's work will allow EPRI and heat pump manufacturers to calculate the benefits—direct and indirect—associated with all the possible design features. Manufacturers can then set more rational goals for product development."

Also, this research may one day become the basis for choosing the "right" advanced heat pump for a particular area, Calm suggests. A utility company or even an individual buyer could determine which combination of features, of all the options available on the market, would yield the biggest savings.

Obviously EPRI has confidence in its efforts to influence the marketplace. The advanced heat pump should make its market debut before the end of this decade. If it is a success, it will be a boon to everybody who pays an electric bill. J.C.

Measuring the Two 'Personalities' of Ozone

Ozone is the Jekyll and Hyde of the environment: It's both a boon and a bane to humanity.

Consider its "split personality." Ten miles or so into the Earth's atmosphere, ozone is a lifesaver. It acts as a screen for keeping humans—and every other living thing—from being scorched by the Sun's ultraviolet rays. But on the Earth's surface, ozone is a noxious gas—a byproduct of auto exhaust that federal and local governments go to much trouble to regulate.

At the heart of ozone's odd nature is its behavior as gas. Unlike most others, it is impossible to contain and difficult to measure. While scientists labor over just how much this gas is harming or helping the environment, they need another party to help determine if the sophisticated instruments used to measure ozone concentration on the ground or in the upper atmosphere are providing accurate numbers. The place they turn to is the National Bureau of Standards, where making such acute measurements is a specialty.

The Elusive Gas

Scientists in the NBS Center for Analytical Chemistry routinely provide very accurately measured reference materials that are used to check how well gas analysis equipment performs. But ensuring such accuracy for ozone is tricky. Regulatory agencies responsible for measuring ground-level ozone must periodically calibrate the instruments that gauge ozone concentration. Such calibrations are fairly easy to do on the equipment that measures many of ozone's pollutant gas cousins such as sulfur dioxide or nitrogen dioxide. This is because bottled, pre-measured standards of these gases can be bought from NBS to ascertain equipment performance.

But ozone is different.

"If you have a steel cylinder and you put pure oxygen in it, you can come back in 100 years and the oxygen will still be there," says Dr. Arnold Bass, who manages the NBS ozone calibration laboratory. "But put ozone in there and by the time you finish putting it in and closing the valve, most of it will be gone." What happens, he explains, is that ozone reacts quickly with the container material and is destroyed almost instantly.

Scientists in the NBS Center for Analytical Chemistry routinely provide very accurately measured reference materials that are used to check how well gas analysis equipment performs.

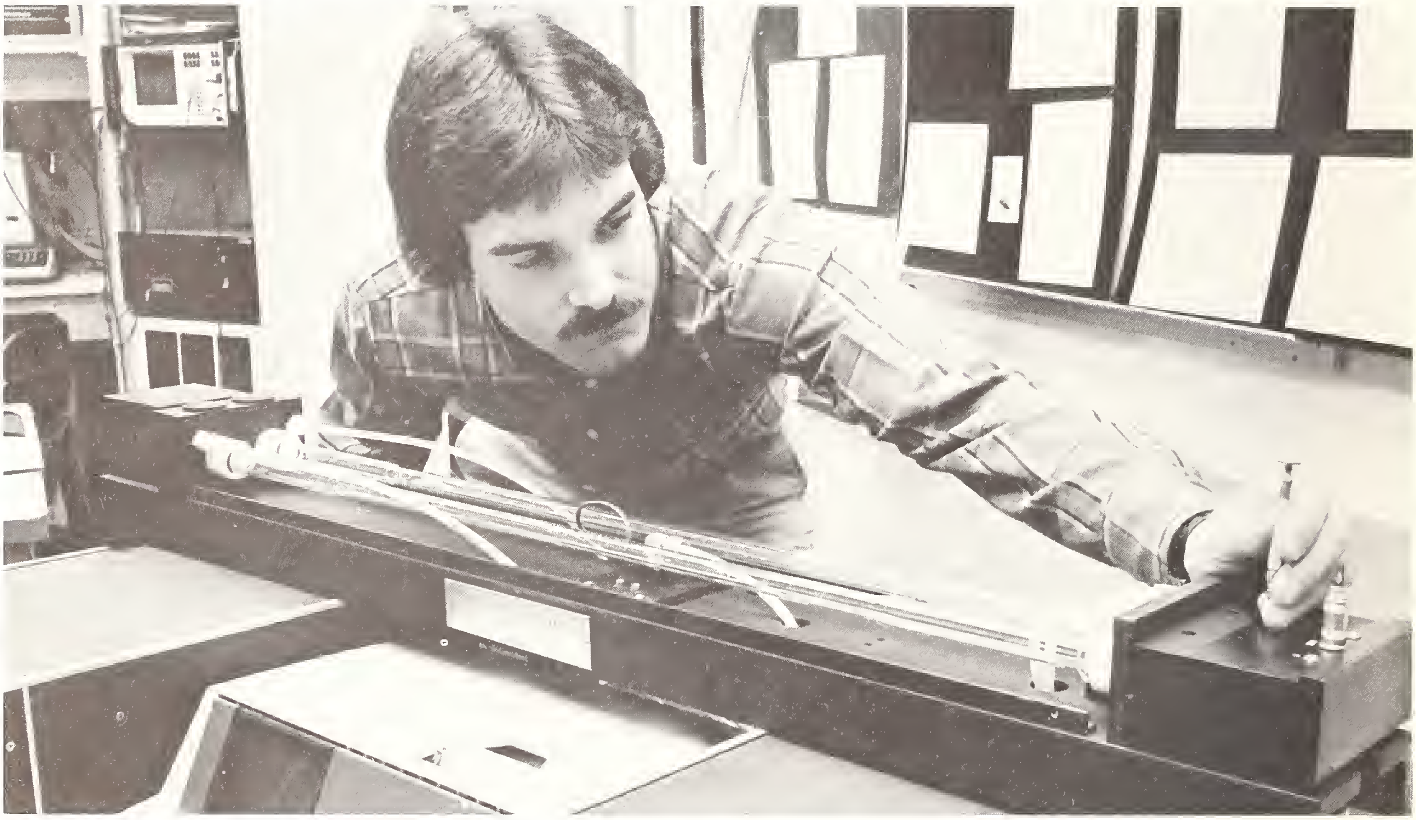
With containment out of the question, scientists look to other ways of measuring the elusive gas. Though there are several techniques for determining ozone concentration, the current method of choice is photometry, developed commercially in the 1970's as an alternative to the messier, less reliable "wet chemical" methods used for years. (Environmental ozone is regulated by the U.S. Environmental Protection Agency [EPA], but controls are administered by local governments which can use EPA photometry standards to ensure accurate readings. EPA turns to NBS, which has no regulatory authority, for technical assurance that the standards are accurate.)

NBS uses a device, appropriately dubbed an ozone reference photometer, to calibrate the EPA standards. First developed at the Bureau in 1976 at the request of EPA, this standard began as a bulky, 10-foot-long device. With the help of Dr. Richard Pauer of EPA, it has since been reinvented and shrunk to about one-third its original size. Now it's portable and 50 times more sensitive than the earlier device. The changes can be attributed, Bass says, to "improved technology and streamlined design."

Shedding Light on a Sample

Photometers—whether they are used in the field for environmental measurements or in the laboratory as standards—work on the principle that ozone absorbs light in the ultraviolet (UV) portion of the spectrum proportionate to the concentration of the gas. By shining UV light through an air sample, scientists can calculate the ozone concentration in that sample by determining the difference in light intensity between the entrance and exit points of the air sample container. At NBS, researchers have worked out methods where a known quantity of ozone can be produced by the NBS reference photometer, then fed into another monitoring instrument, such as a photometer maintained by EPA, to check its accuracy. If the monitoring instrument comes up with the same readings as the NBS standard, it is working properly. Otherwise, the instrument will have to be recalibrated.

EPA requires local agencies to use photometry for ozone measurement and depends on NBS to assure the accuracy of ozone instruments. NBS initially accomplished this by having agencies come to the Bureau to calibrate their instruments against the NBS



NBS technician Jim Norris adjusts the Bureau's ozone reference photometer which is used as a "definitive" standard for calibrating the reference photometers in EPA regional laboratories.

standard. But now NBS is in the process of building photometer standards that can be placed in EPA regional laboratories across the country so local governments can take their photometers to those labs for calibration. The EPA labs will then periodically check their instruments against the NBS reference photometer. EPA's central laboratory near Raleigh, N.C., is equipped with a photometer standard supplied by NBS, as are EPA labs in California and New Jersey. Four more of the devices will be delivered by the end of this year.

"Without a photometer standard, all the user in the field can do is check his instrument's results against those of a neighboring locality, and in that situation, both instruments may be wrong," says Larry J. Purdue, acting director of the quality assurance division of EPA. "What [the NBS reference photometer] will do is find photometers in the field that are not working properly. Users then will have to do maintenance on their defective equipment."

Concern about ozone measurements has also prompted industrial firms to consult NBS. For example, one manufacturer of office machines has requested NBS assistance in determining the levels of ozone that might be produced by photocopiers. And a large aircraft company has asked for measurement help from NBS in its study of the effects of breathing ozone from the stratosphere on people aboard a plane.

The bad name ozone gets as a pollutant underscores its highly reactive nature—that is, the gas reacts chemically with just about everything it comes in contact with. If inhaled, ozone can act as a strong oxidant, reacting with lung tissue and irritating the respiratory tract. And it can cause wear on car tires by reacting with rubber. "Just how much an effect it has on tires we don't know," says Bass. "We do know that if you leave a box of rubber bands in an ozone environment in the laboratory for a month, they'll just fall apart."

There's a Good Side Too

Ozone is not all bad. In fact, if the layer of ozone that surrounds the Earth 10 to 30 miles up—which screens the harmful UV rays of the sun—were to be seriously diminished, scientists predict that crops would dry up, the Earth's oxygen cycle would be interrupted, and skin cancer would become epidemic. That's why researchers worldwide have studied the ozone layer extensively to determine if it is being depleted, and if so, how to head off disaster.

"Whether the ozone is on the ground or in the upper atmosphere, someone needs to be responsible for the accuracy of ozone measurements. And that's what our job is."

Many suspected causes of ozone depletion have been studied in the last decade, the most celebrated probably being the chlorofluorocarbons formerly found in nearly all refrigeration equipment, hairsprays, and spray deodorants. These compounds have since been removed from many products, but the effects of when they were used as propellants in spray cans remain.

"The problem with chlorofluorocarbons is that they are stable and inert, so when they are released they just drift up into the atmosphere and there's nothing to remove them on the way up. They just keep going," says Bass. "When they get high enough the action of the Sun can release chlorine atoms and start a chain reaction that reacts very quickly with ozone, destroying many ozone molecules. It could take as long as 100 years to decompose the fluorocarbons that are already in the atmosphere." There are other suspected ozone destroyers, such as methane gas produced by rice paddies and grazing animals, and even airplane exhaust.

Resetting the Table

Before any conclusions can be made about the state of the Earth's ozone layer, scientists must find out just how much ozone is in the atmosphere compared to how much was once there. This is done by sophisticated instruments that measure the ozone layer from the Earth and from the sky through balloons, high-altitude planes, rockets, satellites, and in the future, the space shuttle. Many of these instruments work on the same principle of UV absorption as photometers. However, in order to reliably monitor the ozone composition of the high atmosphere as contrasted with that determined at ground level—two measurements that ideally should agree—scientists need an accurate system of measuring the transmission of UV radiation through the atmosphere.

NBS has contributed to these measurements by developing—in cooperation with the National Aeronautics and Space Administration Upper Atmosphere Research Office—a table of 1,200 measurement points that indicates how much UV radiation will be absorbed at various temperatures and at different wavelengths of ultraviolet light. This table of values, or cross sections, refines a French study done in 1953 under which ground-based and airborne instrument results varied as much as 8 percent. The NBS research has cut these differences to no more than 2 percent.

"What we've done is to reduce greatly the discrepancy between the two methods of observing atmospheric ozone so the differences that remain may reflect differences in other aspects of the monitoring," Bass says. "Now someone who is making these measurements, and needs to interpret what the distribution of ozone is in the atmosphere, can use these cross sections for that interpretation. The measurement system is much more accurate now."

The Bureau's work in this area has been recognized internationally. For example, in September 1984, at the Quadrennial Ozone Symposium in Halkidiki, Greece, the International Ozone Commission recommended that the NBS ozone cross-section table be accepted as the international standard for determining ozone concentration from satellite instruments.

Ozone's strange nature will no doubt continue to prompt debate over whether the ozone layer is depleting, as well as concern over the gas as a pollutant. The environment's Jekyll and Hyde isn't about to go away anytime soon. But, as NBS' Bass says: "Whether the ozone is on the ground or in the upper atmosphere, someone needs to be responsible for the accuracy of ozone measurements. And that's what our job is." J.H.

New Ultraviolet Wavelength Standards Will Aid Astronomy

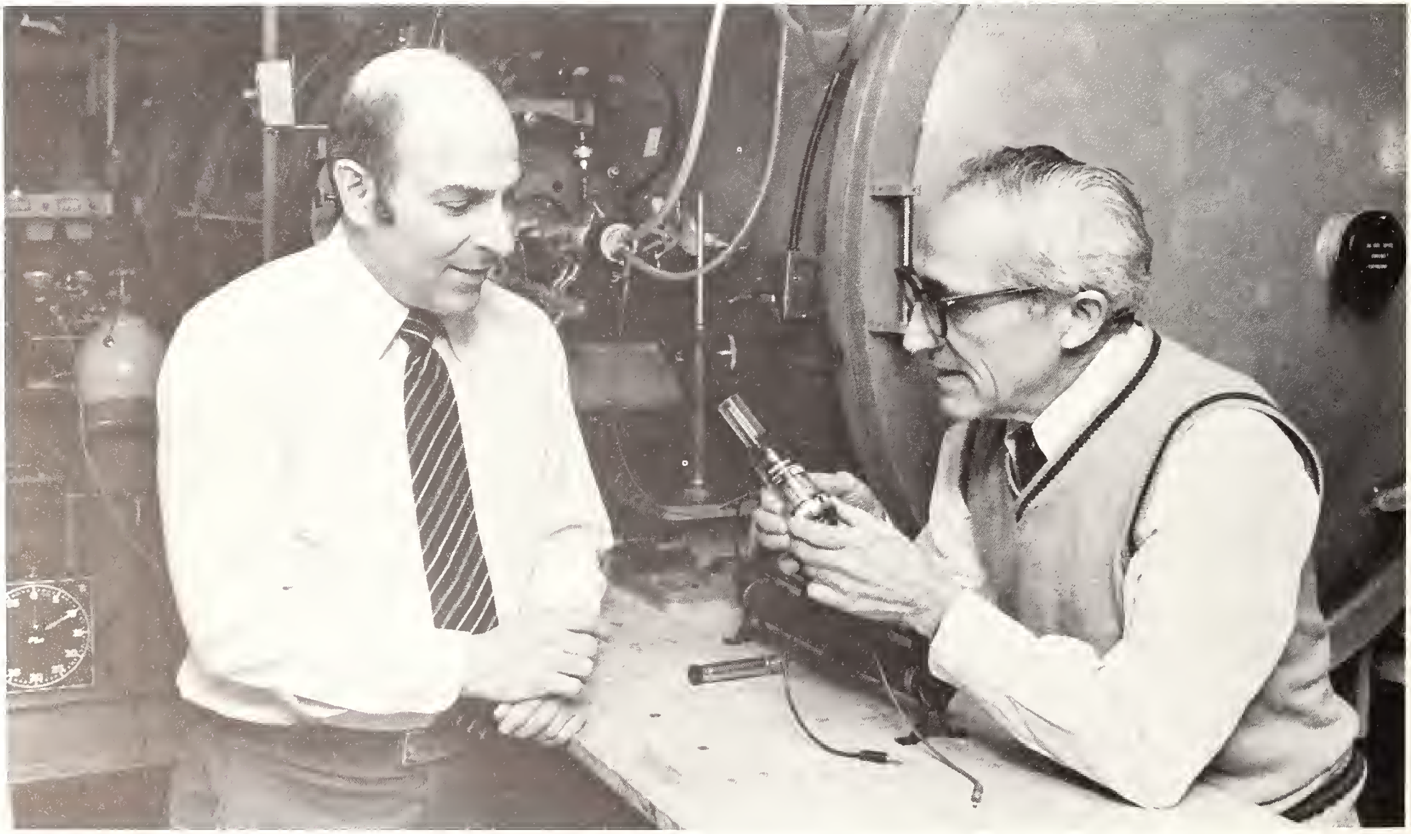
Celestial matters are of no direct concern to Dr. Joseph Reader, a physicist with the National Bureau of Standards. He spends much of his time in a laboratory buried under earth and otherwise shielded from the outside world.

Nevertheless, Reader is abetting astronomy in this underground spectrographic facility with the aid of Nicolo Acquista, another NBS physicist. Reader and Acquista are measuring—to an accuracy of 1 part in a million—some 3,000 wavelengths of ultraviolet radiation emitted by platinum gas in the range of 110 to 380 billionths of a meter.

The National Aeronautics and Space Administration's (NASA's) Edwin Hubble Space Telescope will use these wavelength measurements as the basis for automatically converting high-resolution observations made with a spectrograph into accurate data. From such data, astronomers expect to derive much important new information on the nature and dynamics of the local universe and develop a scale for measuring cosmic distances (see box).

The Space Telescope is the most ambitious project in the history of astronomy. It is a new unmanned astronomical observatory scheduled for launch into Earth orbit late in 1986. Its unmatched visual powers should look on our galactic neighborhood with 10 times better clarity than ever before and also probe seven times deeper into the recesses of the cosmos, perhaps to the very edge of the known universe.

The Space Telescope's inherent capability for high spectral resolution, or clarity, is resident in its ultraviolet High Resolution Spectrograph. This spectrograph was specially designed and built for the new observatory, as were its four other state-of-the-art scientific instruments: a spectrograph for looking at faint distant objects, two cameras, and a photometer—a high-technology counterpart of a photographer's light meter.



Shown in the NBS atomic spectroscopy laboratory are Dr. Joseph Reader (left) and Nicolo Acquista. Acquista is holding a platinum lamp similar to the one that will fly in the Space Telescope.

What a Spectrograph Does

A spectrograph is an observing and recording instrument that produces pictures with diffracted light. The pictures are rows of threadlike parallel lines. Each highly resolved line represents a particular wavelength of electromagnetic radiation produced by a particular type of atom or molecule. Furthermore, each line is part of a unique pattern, or spectrum, of lines. Thus, astronomers can determine what an object in space is made of chemically by identifying spectral patterns.

They can also glean other types of information with a spectrograph. From the intensity of light (number of photons per second) associated with a spectral pattern, they can infer how much of a particular element or type of molecule is present in a celestial object and distinguish physical, as well as chemical, composition. Deuterium and hydrogen are chemically indistinguishable, for example, but deuterium—sometimes called heavy hydrogen—is an isotope with twice the mass of hydrogen. The ability to distinguish isotopes and determine the relative proportions of constituents is key to understanding the dynamics of the universe, present, past, and future, including the processes going on inside our Sun.

From such data, astronomers expect to derive much important new information on the nature and dynamics of the local universe and develop a scale for measuring cosmic distances.

Last, but far from least, astronomers can figure how fast and in which direction—toward or away from the Earth—an object is moving by comparing spectral lines from space with a reference spectrum of lines from a calibration lamp in a "rest state" relative to the spectrograph. (See box for the importance of determining the velocity of celestial objects.)

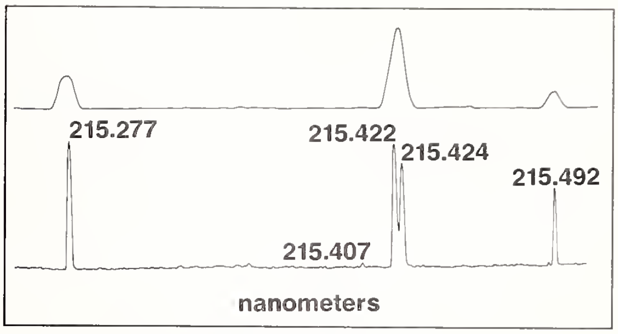
Calibrating the Picture

A spectrographic picture is really a wavelength "ruler" with the shortest wavelength on the scale represented by the spectral line at the beginning of the row, and the longest wavelength by the line at the end of the row. The wavelength associated with any line in between can be calculated on the basis of its position relative to known reference lines.

In the High Resolution Spectrograph, the reference lines will be produced by the platinum lamp, and they will be characterized—each of the lines will be designated according to wavelength—by computer, with Reader's wavelength standards. The computer will derive the wavelengths represented by the unknown lines in the same "picture" from their spatial relationship to the known lines of platinum.

Reader's standards—which will be completed by January 1986—are the only component of the High Resolution Spectrograph's calibration system that must be specially developed. The platinum lamp was invented in the late 1970's by Johns Hopkins University and the Westinghouse Electric Corporation for another NASA satellite observatory, the International Ultraviolet Explorer. The lamp is now available commercially.

But the only wavelength standards as yet available for characterizing the lamp's emissions are 10 times too poorly determined for the High Resolution Spectrograph. If used, they would convert high-resolution observations—the instrument has a resolving power of up to 100,000*—to low-resolution data, says Dr. William Martin, head of the NBS atomic spectroscopy group to which Reader belongs.

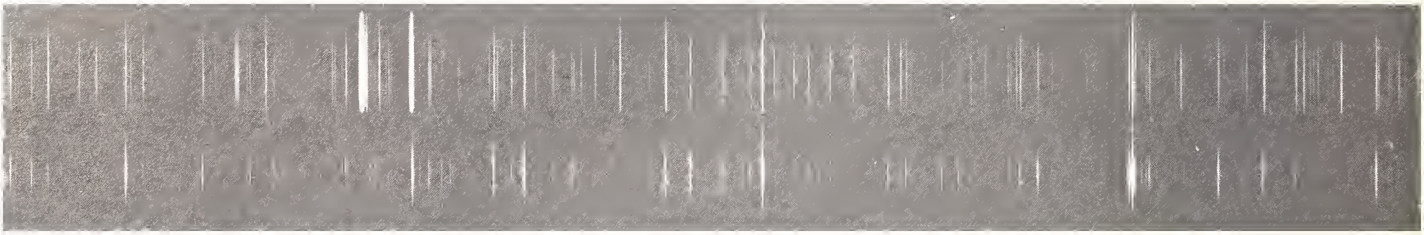


These two strip-chart recordings are spectrograms in diagram-form that show by comparison the extent to which Reader's new determinations will improve platinum wavelength standards for the far ultraviolet. Existing platinum standards were resolved at 30,000, as represented by the top tracing, and measured with an accuracy of 1 part in 100,000. The new standards (bottom) are being resolved at 150,000 and are accurate to about 1 part in 1 million. Note that one broad peak in the top tracing becomes twin peaks—separate wavelengths—at the higher resolution.

Martin keeps abreast of developments in astronomy because his group traditionally supplies a measurement base for that area. Two years ago he read about the Space Telescope's platinum-lamp calibration standard, and he suspected that new platinum wavelength standards would be needed. Reader made some high-resolution measurements on platinum and confirmed Martin's suspicions.

Together, they drew up a proposal that NBS develop the standards and submitted it to NASA

* Resolving power—or resolution—as the term applies to a spectrograph, is the instrument's ability to distinguish one wavelength of radiation from another. The extent of this ability is determined by dividing the average wavelength of the two closest discernible spectral lines by the difference in wavelength between those lines.



Above are two spectrograms recorded on a single photographic plate by the 35-foot NBS vacuum-ultraviolet spectrograph. The top spectrum contains spectral lines of both platinum and copper over the wavelength range 148 to 154 nanometers. The bottom spectrum consists of platinum lines only, in the same wavelength range.

and the Space Telescope Science Institute in Baltimore. The institute is operated by a consortium of some 17 American universities for NASA and the European Space Agency.

"New standards are absolutely necessary," Martin explains. "And I don't know anybody but NBS that could develop them to the required accuracy. Most wavelength measurements of the highest accuracy in the far ultraviolet are made here. We have the most extensive vacuum-ultraviolet facility in the world, and we can make better measurements [in that region] than anybody else. We have the expertise and the capability built in."

The High Resolution Spectrograph's design team and officials at NASA and the Space Telescope Science Institute reviewed the NBS proposal. They quickly concurred: NASA would fund the development by NBS of the required standards.

One of the members of the design team is Dr. Jeffrey Linsky, an astronomer with the Joint Institute for Laboratory Astrophysics operated by NBS and the University of Colorado. Linsky says, "Frankly, we knew from the design stage that we would have a problem with the existing wavelength standards—they were developed more than 50 years ago. But before we could even think of doing something about it, the spectrograph had to be built and tested."

When tested, the instrument, built by Ball Aerospace, Inc., exceeded the expectations of the design team. This increased the accuracy required of the wavelength standards. "We were certainly relieved when Martin and Reader came forward and said they could solve the problem," Linsky says.

Linsky says Reader's platinum wavelength measurements "should satisfy astronomy's need for far-ultraviolet standards for at least a decade."

Underground at NBS

It takes an instrument with a long focal length to measure short wavelengths to an accuracy of 1 part in a million. So, in relative size, the vacuum-ultraviolet spectrograph at NBS is the whale of the NBS spectrographic laboratory. It is a bulky, 35-foot-long, self-contained assembly consisting mainly of a large hollow pipe.

A vacuum pump evacuates air from this pipe to create a vacuum between the emission source at one end of the pipe and the optical equipment and photographic plate at the opposite end. This is necessary because the Earth's atmosphere absorbs wavelengths below 200 nanometers (200 billionths of a meter)—hence this region is referred to as the "vacuum ultraviolet." If we could see in this region, the air would literally be as clear as mud. For this reason, ultraviolet astronomy must be carried out in space, above the atmosphere.

Reader is using the vacuum spectrograph for comparative analyses of the spectra of copper and platinum. Ionized copper emissions in the ultraviolet are the well-characterized—in large part by Reader—but difficult-to-produce reference spectrum used by laboratory spectroscopists interested in making vacuum-ultraviolet wavelength measurements.

Astronomer Linsky predicts this will change. A commercially available platinum lamp and new platinum-wavelength standards, he says, will make platinum emissions the ultraviolet laboratory standard.

In the meantime, Reader, as well as every other spectroscopist, has to build his own copper lamp to produce vacuum-ultraviolet reference lines. He has also built a special platinum-copper emission source for the comparative studies on platinum and copper.

His work on platinum does not require measurements below 100 nanometers. In other experiments, however, Reader has determined wavelengths as short as 1 nanometer. That is, he says, the lower limit of optical spectroscopy. Below 1 nanometer, waves cannot be reflected by optical means and other technologies are required for spectral analysis.

Linsky says Reader's platinum wavelength measurements "should satisfy astronomy's need for far-ultraviolet standards for at least a decade."

Reader is pleased to hear this assessment, and amused at an irony. "Here I am doing something for astronomy, and I hardly ever get out of the basement," he says, referring to the time he spends in the NBS spectrographic laboratory. That makes his association with the stars an underground connection. J.C.

Redshift, Blueshift: Why Astronomers Need to Make Accurate Wavelength Measurements

"Velocity is very important in astronomy," says NBS astronomer Jeffrey Linsky. "Many important questions can only be answered by precise velocity measurements.

"For instance," he explains, "if a star has a planet going around it, you won't be able to see the planet directly, but you can infer its presence because its gravitational attraction will make the star wobble."

That wobble may amount to no more than 1 kilometer per second, Linsky says, but it will be detectable, by the High Resolution Spectrograph, as displacements from the rest position of spectral lines associated with the star.

When a prominent line, such as the Lyman alpha line of hydrogen at 122 nanometers, shifts toward the red, or longer wavelength, region of the electromagnetic spectrum, the matter responsible for the feature is moving away from the Earth. A blueshift—toward shorter wavelengths—means the object is moving toward the Earth. In either event, the extent of displacement is the measure of velocity.

In the case of the hypothetical wobbly star, Linsky says, "The velocity of the hydrogen line indicates the velocity of the star relative to the Earth. Over time, as the planet revolves around the star, the velocity of the star shifts from blue to red and back again as the planet pulls the star first toward the Earth—when it is between the star and the Earth—and then away from the Earth when the planet is behind the star. This wobble may only be 1 kilometer per second, but it is enough to reveal the presence of the unseen planet."

This example of how velocity—and therefore wavelength measurement—is used in astronomy could be augmented by countless others. One application is of particular interest in relation to the Space Telescope, however.

Astronomers expect the High Resolution Spectrograph to produce measurements precise enough for "calibrating" a celestial yardstick. If so, they will be able to make reasonably accurate determinations, for the first time in history, of distances outside our solar system and shed more light, perhaps, on the age and extent of the observable universe.

This "calibration" in part consists of determining precisely the extent to which certain Cepheids, or variable stars, seem to expand and contract—in other words, to change their velocity as they seem to move toward the Earth and away. These pulsations, astronomers think, vary strictly according to the intrinsic brightness of the star. Since apparent brightness depends on both intrinsic brightness and distance, astronomers could calculate the distance to any Cepheid of known intrinsic brightness by employing a very simple law: the law of inverse squares. According to this law, familiar to every serious photographer, apparent brightness diminishes by a factor of four every time distance doubles.

Of course, calculations of distance based on brightness will have to take into account many factors, including the amount of light being absorbed by the dark matter that evidently pervades the universe. But the dark matter is yet another subject the Space Telescope will be looking into. And quite another story.

Calibrations for the Space Telescope

The space shuttle will carry a precious astronomical cargo indeed when it ferries the Edwin P. Hubble Space Telescope into orbit next year. Precious in terms of hard currency—the telescope will probably end up costing some $1.5 billion—and high scientific hopes for a better view of the universe than ever before achieved.

These hopes are pinned on the reliable performance of specially designed, state-of-the-art scientific instruments, including two spectrographs. The National Bureau of Standards, through the Atomic and Plasma Radiation Division, is carrying out several calibration projects to help assure that this equipment goes into space ready and able to perform as expected.

Dr. Jules Klose holds a krypton lamp similar to the one he and several of his industrial colleagues calibrated for the Space Telescope.

Dr. Wolfgang Wiese, chief of the division, says these projects involve the development of platinum ultraviolet wavelength standards for the High Resolution Spectrograph and a variety of light-intensity calibrations.* He says the light-intensity projects relate to the independent calibration of both spectrographs and to the retesting of equipment in the assembled telescope.

Dr. Jules Klose is the principal NBS researcher responsible for the intensity calibrations. "Measuring light intensity means, in some form or other, measuring photons—light particles," he explains. For Klose and his associates, working in the NBS vacuum ultraviolet radiometry laboratory, the challenge in regard to the Space Telescope calibrations has been manifold. They have had to:

□ Measure and characterize—in terms of total output, stability of output, and shape of beam—an argon lamp, a krypton lamp, and a hydrogen lamp produced by Quantatec, Inc., and two different platinum-chromium-neon lamps produced by Westinghouse Electric Corporation, all developed for Martin Marietta Aerospace. Two of the lamps were redesigned and constructed according to NBS recommendations. These five light sources are used in a "Space Telescope optical simulator." This is an instrument developed by Martin Marietta Aerospace "to simulate conditions of light coming from weak stars," Klose says. "Together, the lamps produce a continuous band of radiation from the vacuum ultraviolet through the visible." This is the range of the electromagnetic spectrum in which the Space Telescope's Faint Object Spectrograph will operate.

□ Calibrate the Space Telescope optical simulator before and after Martin Marietta used it to calibrate the Space Telescope's Faint Object Spectrograph. The company shipped the simulator to NBS along with a 6-foot vacuum chamber in which it has to be encased during operation. NBS researchers measured the absolute spectral intensities emitted by the five lamps in this device by comparison with the known intensities of argon arc emission sources specially designed and calibrated by NBS. This calibration established an absolute ultraviolet intensity scale for the Faint Object Spectrograph.

□ Develop for Ball Aerospace, Inc., builders of the High Resolution Spectrograph, an argon arc ultraviolet emission standard for use in calibrating that spectrograph.

Klose is now calibrating several platinum-chromium-neon lamps for Martin Marietta to use in retesting the equipment in the assembled Space Telescope. Assembly of the telescope is under way at Lockheed Missiles and Space Company in California. J.C.

* NASA's Goddard Space Flight Center contracted with NBS for the development of the platinum wavelength standards. (See page 24 for a discussion of these standards.) Ball Aerospace and Martin Marietta Aerospace, both under contract to NASA-Goddard, subcontracted to NBS for the remaining work. The Space Telescope Science Institute, which administers the Space Telescope operations, has provided guidance.

NBS Program Boosts Quality of Clinical Measurements

When Dr. John Taylor talks, analytical chemists listen.

They listen to what the NBS chemist tells them about how to improve what they do—that is, make analytical measurements. With Taylor's advice, the 40 or 50 attendees at each of his frequent "quality assurance seminars" return to their laboratories better equipped to arrive at reliable figures for nanograms, milliliters, or any other units within the critical measuring realm of analytical chemistry.

Taylor has been preaching the gospel of good measurement through his seminars on behalf of the National Bureau of Standards. He readily admits that chemistry industry professionals sometimes need help in getting on the right track for their measurement programs, and that's why he started the seminars. "We try to emphasize quality control and quality assurance while giving tips on more precise and accurate measurements," Taylor says.

He has taken the seminars on the road to China, Canada, and cities across the United States. About a dozen of the 70 he has held have been conducted at the main NBS site in Gaithersburg, Md.

Though his 2-day workshops are designed to help a variety of researchers within the analytical chemistry field, they are ideal for clinical chemists who need to know the best tricks of the trade to make measurements accurately at the parts per million level or lower.

The seminars fit well into the mission of the Bureau's clinical chemistry program, which is, simply, to help industries and government agencies make the best possible analytical measurements. Taylor's seminars help NBS reach this goal, as does the Bureau's production of Standard Reference Materials (SRM's) for calibrating equipment and assessing analytical methods.

The current catalog of SRM's lists 900 different items, of which annual sales total about 40,000 units. More than 60 of the SRM's now offered are clinical chemistry standards. And while many are "old favorites" that are consistently in demand, new clinical SRM's are being developed to help solve old problems.

One such example is a Standard Reference Material NBS researchers recently completed for measuring the concentration of lead in blood. Wide-ranging results had been obtained in numerous studies when samples with known lead concentrations were sent to a variety of laboratories. This prompted the National Institute for Occupational Safety and Health to request that NBS develop a standard sample to improve the measurement reliability of lead in blood. The resulting SRM is expected to help improve the accuracy of lead-in-blood measurements.

"We try to emphasize quality control and quality assurance while giving tips on more precise and accurate measurements."

While NBS seminars and Standard Reference Materials are, in a sense, a "reaching out" to industrial, professional, or trade organizations, there are times when a longer-term, more personalized NBS/industry relationship is desirable. The Bureau offers just such an environment through its Research Associate Program. In existence since 1921, the program allows non-NBS scientists and engineers to work closely with NBS staffers and to use the extensive Bureau facilities. Salaries of associates are paid by the sponsoring company or organization. Currently there are 168 research associates at the Bureau, representing 63 companies and organizations.

Though participation in the program can be of great benefit to an industry, NBS also is helped in the process, says Dr. Howard Sorrows, director of the Bureau's Office of Research and Technology Applications. "We learn firsthand the views and needs of the industrial community," he says. "The information we receive from the associates helps us structure our research programs so they are of maximum benefit to industry."

The program has an allure for clinical chemists in that virtually all available analytical techniques are practiced at NBS, and the array of instruments is one of the best in the world. The College of American Pathologists (CAP) has taken advantage of the program by sponsoring research associates in clinical chemistry for 6 years. Most recently a CAP researcher performed work in gas chromatography/mass spectrometry to certify the amount of creatinine in an NBS human serum SRM and in samples used in a CAP laboratory testing program. Measurement of creatinine is an important factor in the analysis of kidney function.

But whether a clinical chemist comes to work at NBS as a research associate, attends an NBS quality assurance seminar, or uses Bureau SRM's, the goal remains the same: better chemical measurements.

For more information about the Bureau's quality assurance seminars, write or call Dr. John K. Taylor, A309 Chemistry Building, National Bureau of Standards, Gaithersburg, MD 20899, 301/921-3497. J.H.

NEW PUBLICATIONS

WEIGHTS AND MEASURES TRAINING TEXT

Introduction to Electronic Weighing and Measuring Systems, *Natl. Conf. on Weights and Measures, inspector's manual, 86 pages (January 1985), instructor's manual, 62 pages (January 1985). Order both from the National Conference on Weights and Measures, P.O. Box 3137, Gaithersburg, MD 20878, $25 prepaid (or inspector's manual, $10 prepaid; instructor's manual, $15 prepaid).*

A recent training text has been published by the National Conference on Weights and Measures (NCWM) under a grant from NBS. The text is the first of 36 to be written and published during the next 6 years. Technological advances in the application of electronics and microprocessing to commercial devices have created a need for special training of weights and measures officials nationwide. These texts are designed to provide the states with the material they need to conduct their training programs. Each text, called a training module, is composed of two volumes—an inspector's manual and an instructor's manual. Provided with the instructor's manual are instructional aids, including 35-mm slides designed for classroom presentation of the training material.

TEST CHIP DESIGN PROCEDURES

Carver, G.P. and Wachnik, R.A., ***TERRY-2: A Test Chip for Characterization of the Performance of Buried-Channel Charge-Coupled Device (CCD) Imagers,*** *Natl. Bur. Stand. (U.S.), NBSIR 84-2894, 135 pages (December 1984). Order from NTIS by stock no. PB 85-137701, $14.50 prepaid.*

This NBS report will aid electronics firms that design test chips and methods for automated measuring of material and process properties in integrated circuit fabrication. The product of a detailed study performed by the Bureau's Center for Electronics and Electrical Engineering, the report is a recounting of how NBS scientists designed the 5-mm-square TERRY-2 chip for testing charge-coupled device (CCD) imagers. Included are descriptions of chip components—resistors, capacitors, transistors, and other test structures. There are also hints for developing and implementing a test program for drop-in test chips, which interested companies can adapt for their own use.

INTRODUCTION TO DATAPLOT

Filliben, J.J., ***DATAPLOT—Introduction and Overview,*** *Natl. Bur. Stand. (U.S.), NBS Spec. Pub. 667, 112 pages (June 1984). Order from NTIS by stock no. PB 84-214055, $13 prepaid (paperback), $4.50 prepaid (microfiche).*

NBS has published a reference manual for DATAPLOT, a high-level, interactive programming language developed at NBS for analyzing scientific data, plotting data on continuous or discrete graphs, and performing linear or non-linear curve-fitting. The text includes a general introduction to DATAPLOT and a guide, with examples, to the various commands and features of the language. DATAPLOT is written in ANSI FORTRAN and is easily transported to a variety of systems. Known implementations exist on Univac, Vax, Honeywell, IBM, Data General, Perkin Elmer, and Prime computers.

OPTICAL FIBER MEASUREMENTS

Day, G.W. and Franzen, D.L., editors, ***Technical Digest—Symposium on Optical Fiber Measurements, 1984,*** *Natl. Bur. Stand. (U.S.), NBS Spec. Pub. 683, 148 pages (October 1984). Order from GPO by stock no. 003-003-02604-2, $5 prepaid.*

Summaries of 31 papers presented at an October 1984 symposium on optical fiber measurements in Boulder, Colo., are now available. The papers deal with measurements on single and multimode fibers, the characterization of fiber for sensors, instrumentation and field measurements, and standards.

PROGRAMMING LANGUAGE SELECTION

Cugini, J.V., ***Selection and Use of General-Purpose Programming Languages—Overview*** *(Vol. 1) and* ***Program Examples*** *(Vol. 2), Natl. Bur. Stand. (U.S.), NBS Spec. Pub. 500-117 (Vol. 1 and Vol. 2), 81 and 178 pages, respectively (October 1984). Order from GPO: Vol. 1 by stock no. 003-003-02612-3, $3 prepaid; Vol. 2 by stock no. 003-003-02613-1, $5.50 prepaid.*

A two-volume set of publications issued by the NBS Institute for Computer Sciences and Technology should help data processing managers and users select the right language for their special requirements. Volume 1 explains the features of seven popular programming languages—Ada, BASIC, COBOL, C, FORTRAN, Pascal, and PL/1—and points out special advantages and disadvantages for each. Selection criteria discussed are the language and how it is to be used, the application to be programmed, and the user's existing facilities and software. Volume 2 contains program examples to help illustrate the features of the various languages.

SIMPLIFIED SCALE INSPECTIONS

Warnlof, O.K., editor, ***Specifications, Tolerances and Other Technical Requirements for Weighing and Measuring Devices,*** *Natl. Bur. Stand. (U.S.), NBS Hdbk. 44—1985, 294 pages (November 1984). Order from GPO by stock no. 003-003-02625-5, $9 prepaid.*

The jobs of hundreds of state inspectors who regulate weighing and measuring scales will be simplified due to major revisions by the National Conference on Weights and Measures (NCWM) in this handbook. NCWM's Specification and Tolerance Committee has worked with the Scale Manufacturers Association in developing new tolerance procedures whereby the allowable error increases with the size of the load up to the maximum capacity of the scale. The new code in Section 2.20 of the handbook, Scales, which becomes effective January 1, 1986, eliminates complicated calculations for each type of scale and enables manufacturers to produce products that are compatible with foreign codes.

PERSONAL COMPUTER SECURITY

Steinauer, D.D., ***Security of Personal Computer Systems: A Management Guide,*** *Natl. Bur. Stand. (U.S.), NBS Spec. Pub. 500-120, 66 pages (January 1985). Order from GPO by stock no. 003-003-02627-1, $3 prepaid.*

Security risks are increasing as personal computers become as common in the office as electric typewriters. No "cookbook" approach can solve security problems for every organization. But in this booklet the experts in the NBS Institute for Computer Sciences and Technology recommend several basic steps that will help. They suggest a prompt inventory of personal computer equipment, noting where it is located and who uses it. A risk analysis will help determine how vulnerable your information is. Then cost-effective controls can be put in place, ranging from an inexpensive lock to specially designed software or hardware.

LASER-INITIATED COMBUSTION OF ALLOYS

Bransford, J.W., ***Laser-Initiated Combustion Studies on Metallic Alloys in Pressurized Oxygen,*** *Natl. Bur. Stand. (U.S.), NBSIR 84-3013, 76 pages (August 1984). Order from NTIS by stock no. PB 85-28114, $10 prepaid.*

In 1981, NBS provided qualitative data on the combustion of several aluminum, stainless steel, and copper alloys (NBSIR 81-1647). Since then, quantitative data have been acquired on aluminum-, cobalt-, iron-, and nickel-based alloys. These data include measurements for ignition and combustion temperatures and other combustion parameters at high-oxygen pressures. It was found that aluminum could be ignited below the melting point of the alloy oxides produced. Cobalt-, iron-, and nickel-based alloys generally ignited slightly below to slightly above the melting range of the respective alloy. Unsupported combustion was not achieved until the alloys and oxides were melted. These experiments and results are described in this publication.

INSTALLATION OF WOOD-BURNING APPLIANCES

Loftus, J.J. and Peacock, R.D., ***Clearances and Methods of Protection for Wall and Ceiling Surfaces Exposed to Radiant Heating Appliances,*** *Natl. Bur. Stand. (U.S.), NBS Tech. Note 1205, 112 pages (December 1984). Order from GPO by stock no. 003-003-02630-1, $4.50 prepaid.*

Accompanying the increasing use of wood-burning appliances over the past 10 years has been a dramatic increase in house fires. Mainly, say NBS fire researchers, because homeowners improperly install, operate, and maintain these appliances. In recent studies for the Consumer Product Safety Commission and the Department of Energy, the NBS researchers have investigated the fire safety of wood-burning appliances. The report gives the results of these studies and recommendations for building and fire code officials to use in preparing fire safety codes and regulations. Many of these guidelines have been adopted by the National Fire Protection Association (NFPA) as changes to NFPA's code on heat-producing appliances.

THERMODYNAMIC DATA FOR AQUEOUS AND BIOCHEMICAL SYSTEMS

Goldberg, R.N., ***Compiled Thermodynamic Data Sources for Aqueous and Biochemical Systems: An Annotated Bibliography (1930-1983),*** *Natl. Bur. Stand. (U.S.), NBS Spec. Pub. 685, 106 pages (December 1984). Order from GPO by stock no. 003-003-02606-9, $4.50 prepaid.*

NBS has compiled an annotated bibliography of sources of data on the thermodynamic properties of aqueous and biochemical systems. The bibliography lists 162 different sources of compiled and evaluated chemical thermodynamic data such as Gibbs energy and equilibrium data, enthalpies of formation and reaction, heat capacities and entropies, and the corresponding partial molar and excess properties. Derived quantities used to calculate data and some transport and mechanical data are also included. The bibliography covers publications released between 1930 and 1983, and includes brief descriptions of the types of properties tabulated in each source, the classes of materials dealt with, and the degree of completeness of the compilation. It is indexed by author and subject.

SHIELDING EFFECTIVENESS OF BUILDINGS

Wyss, J.C., Anson, W.J., and Orr, R.D., ***Building Penetration Project,*** *Natl. Bur. Stand.(U.S.), NBSIR 84-3009, 310 pages (September 1984). Order from NTIS by stock no. PB 85-126001, $25 prepaid.*

Electrical engineers and others concerned with the effectiveness of buildings in shielding their interiors from electromagnetic (EM) radiation will be interested in this publication from NBS. It documents a computer program which calculates building attenuation of EM radiation over the frequency range 10 kHz to 10 GHz. Attenuation is computed from building shape, dimensions, room layout, and the electrical properties of the construction materials; no electromagnetic measurements are required. Although performed for the U.S. Army, the work is applicable to almost any situation where it is desirable to estimate the extent of penetration of EM radiation into a multiroom, one-story building.

ORDERING INFORMATION

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

CONFERENCE CALENDAR

11th International Conference on Atomic Collisions in Solids, Georgetown University, Washington, DC

August 4-9, 1985

The subject atomic collisions in solids deals with the fundamental aspects of particle interactions with matter in a condensed state. It crosslinks not only the basic fields of elementary particle, nuclear, atomic, molecular, and solid state physics but also topical areas such as surface chemistry, physics, and radiation effects on matter. The International Conference on Atomic Collisions in Solids, held every 2 years since 1965, is one of the few conferences that truly bridges these disciplines. The conference addresses the scientific underpinnings of such important technologies as submicron devices and new materials used in a variety of applications. Sponsored by NBS, Georgetown University, and the International Union of Vacuum Science, Techniques, and Applications. Contact: Kathy C. Stang, A353 Physics Building, NBS, Gaithersburg, MD 20899, 301/921-2255.

EMI Metrology Short Course, University of Colorado, Boulder, CO

August 6-8, 1985

This course will bring together engineers, scientists, technicians, and managers from industry, government, and academia for the most up-to-date information on instruments and techniques for measuring electromagnetic interference. Topics to be covered include: open-site measurement as related to FCC requirements; TEM cells; shielding effectiveness; anechoic chambers; probes; reverberating chambers; and measurement services. Sponsored by NBS, it will be held at the University of Colorado Boulder campus with demonstrations at the NBS Boulder laboratories. Contact: Kent Zimmerman, Office of Conference Services, Campus Box 153, University of Colorado, Boulder, CO 80309, 303/492-5151.

Time and Frequency Seminar, NBS, Boulder, CO

August 13-15, 1985

This seminar is intended for those who want a comprehensive introduction to the generation and dissemination of time and frequency. It will include demonstrations of practical means for making time and frequency measurements as well as tours of NBS time and frequency facilities. Topics will include: types of frequency standards and their operational principles; mathematical characterization of clocks and frequency standards; measurement of clock stability in both time and frequency domains; pitfalls in data collection and analysis; the process of timekeeping; NBS dissemination services; and NBS frequency calibration services. Sponsored by NBS. Registration fee is $575. Contact: Judy Rapozo or James L. Jespersen, Division 524, National Bureau of Standards, Boulder, CO 80303, 303/497-3294 or 303/497-3849.

VLSI Chip Packaging Workshop, Gaithersburg Marriott, Gaithersburg, MD

September 9-11, 1985

This workshop has become a premier forum for technical professionals in the field of package development and analysis for VLSI integrated circuits. The topics covered will include large chips, high-lead-count packages, conventional and pin-grid-array chip carriers, TAB and wire bonding, and electrical and thermal performance packages. Sponsored by the Institute of Electrical and Electronics Engineers, the Component Hybrids and Manufacturing Technology Society, and NBS. Contact: for technical information, Courtland Robinson, AT&T Bell Labs, Allentown, PA 18105, 215/439-5166; for registration information, Sandy Kelley, B344 Technology Building, NBS, Gaithersburg, MD 20899, 301/921-3541.

2nd International Symposium of Roofing Technology, NBS, Gaithersburg, MD

September 18-20, 1985

The theme of this symposium will be "Roofing Materials and Practices—A Decade of Change and Future Trends." The speakers will focus on such topics as: future technologies in roofing; advances in roofing membranes; the impact of computers on roofing design; roofing condition assessment; quality assurance; practical experiences in design, application, and field performance; metal roofing, flashings, and accessories; and steep roofing. Sponsored by NBS, the U.S. National Roofing Contractors Association, and the International Union of Testing and Research Laboratories for Materials and Structures (RILEM). Contact: Robert G. Mathey, B348 Building Research, NBS, Gaithersburg, MD 20899, 301/921-2629.

First International Symposium on Fire Safety Science, NBS, Gaithersburg, MD

October 7-11, 1985

Approximately 114 papers will be presented at the First International Symposium on Fire Safety Science by speakers representing 13 countries. The symposium's ten sessions will cover such topics as fire physics; fire chemistry; smoke toxicity and toxic hazard; statistics, risk, and system analysis; people-fire interactions; detection; suppression; structural behavior; specialized fire problems; and translation of research into practice. The meeting has been organized by an ad hoc committee with a view to initiating an International Association for Fire Safety Science. The purpose is to provide a continual forum dedicated to all aspects of fire science and their application to solving problems presented by destructive fire. Sponsored by NBS. Contact: Sonya Cherry, B260 Polymer Building, NBS, Gaithersburg, MD 20899, 301/921-3245. ■

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 Center for Materials Science.

THE NATIONAL MEASUREMENT LABORATORY

Provides the national system of physical and chemical measurement; coordinates the system with measurement systems of other nations and furnishes essential services leading to accurate and uniform physical and chemical measurement throughout the nation's scientific community, industry, and commerce; provides advisory and research services to other government agencies; conducts physical and chemical research; develops, produces, and distributes Standard Reference Materials; and provides calibration services. The laboratory consists of the following areas:

- Standard Reference Data
- Measurement Services
- Basic Standards
- Radiation Research
- Chemical Physics
- Analytical Chemistry

THE NATIONAL ENGINEERING LABORATORY

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

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

THE INSTITUTE FOR COMPUTER SCIENCES AND TECHNOLOGY

Conducts research and provides scientific and technical services to aid federal agencies in the selection, acquisition, application, and use of computer technology to improve effectiveness and economy in government operations in accordance with Public Law 89-306 (40 U.S.C. 759), relevant Executive Orders, and other directives; carries out this mission by managing the Federal Information Processing Standards Program, developing federal ADP standards guidelines, and managing federal participation in ADP voluntary standardization activities; provides scientific and technological advisory services and assistance to federal agencies; and provides the technical foundation for computer-related policies of the federal government. The institute consists of the following centers:

- Programming Science and Technology
- Computer Systems Engineering

THE CENTER FOR MATERIALS SCIENCE

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

- Nondestructive Evaluation
- Inorganic Materials
- Fracture and Deformation
- Polymers
- Metallurgy
- Reactor Radiation

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