Facilities

National Institute of Standards and Technology

U.S. DEPARTMENT OF COMMERCE
National Institute of Standards and Technology

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NIST Boulder Laboratories

Foreword

Our number one job at the National Institute of Standards and Technology is to work closely with industry on the development and use of the new technologies that U.S. companies need to stay competitive in the world marketplace. We also have major responsibilities to help other government agencies and universities.

Founded in 1901 as the National Bureau of Standards, NIST has enjoyed a long history of cooperative research with scientists and engineers from industry, government, and academia. This tradition of cooperation is more important now than ever before.

When the Institute was created from NBS on August 23, 1988, as a result of the Technology Competitiveness Act, we received a number of new assignments. The aim is to further assist industry in developing technology and procedures for improving quality, and to facilitate the commercialization—especially by small- and mid-sized U.S. firms—of products derived from new scientific discoveries.

One of the ways we are pursuing these goals is to make many of our research and testing facilities—some of which are unequaled anywhere in the world—available to other researchers for collaborative or independent work. For example, our Research Associate Program, begun in the 1920's, has spawned numerous collaborative projects over the years. Through this program, sponsoring organizations pay the salaries of research associates; NIST contributes its wide-ranging expertise and permits the use of its facilities and equipment.

We also encourage U.S. researchers to conduct proprietary work in select Institute facilities on a cost-recovery basis when equal or superior facilities are not otherwise readily available. We hope through these actions to increase the transfer of technology to industry and to encourage more commercially important research.

This brochure highlights only a small number of the special NIST facilities which could be used to benefit your research. It offers information on the capabilities of these facilities as well as their availability. Individuals or organizations who wish to use an NIST facility should contact the appropriate facility manager.

We invite you to profit from our nation's investment in NIST and to work with us to sustain our country's technological and commercial leadership.

Ernest Ambler

Ernest Ambler
Director

NIST Research Reactor

The National Institute of Standards and Technology research reactor is a national center for the application of reactor radiation to a variety of problems of national concern. Major program areas at the reactor include the application of neutron scattering methods to research in materials science, trace analysis by neutron activation, nondestructive evaluation (via neutron radiography and scattering), neutron standards and dosimetry, and isotope production and radiation effects.

Capabilities:

The NIST reactor is a cooled and heavy-water moderated reactor operating at 20 MW and producing a peak thermal core flux of 4×10^{14} neutrons/cm^2. A large cold neutron source has been installed which will increase the flux of long wavelength (>1 nm) neutrons by a factor of 3 to 5.

Experimental facilities are available for neutron single-crystal and powder diffraction and inelastic scattering studies, small-angle neutron scattering (SANS), sample preparation, irradiation and post-irradiation processing, neutron depth profiling, neutron dosimetry, and related physics.

Applications:

Elastic Scattering. Atomic-scale phase structure in catalysts, electronic and dielectric ceramics, semiconductors, and biomaterials, for example. Submicron structure studies including molecular conformations in block copolymers, characterization of microcracks and porosity damage in ceramics, creep cavitation in metal alloys, and characterization of precipitate distributions in high-strength, low-alloy steels. Phase transition kinetic studies in alloys. Atomic-level magnetic structure and behavior in crystalline and amorphous materials.

Inelastic Scattering. Lattice dynamics and vibrational spectroscopy studies of hydrogen in metals at low concentrations, vibrational spectra of molecules adsorbed in heterogeneous catalysts, diffusion processes for small molecules in solids, magnetic properties.

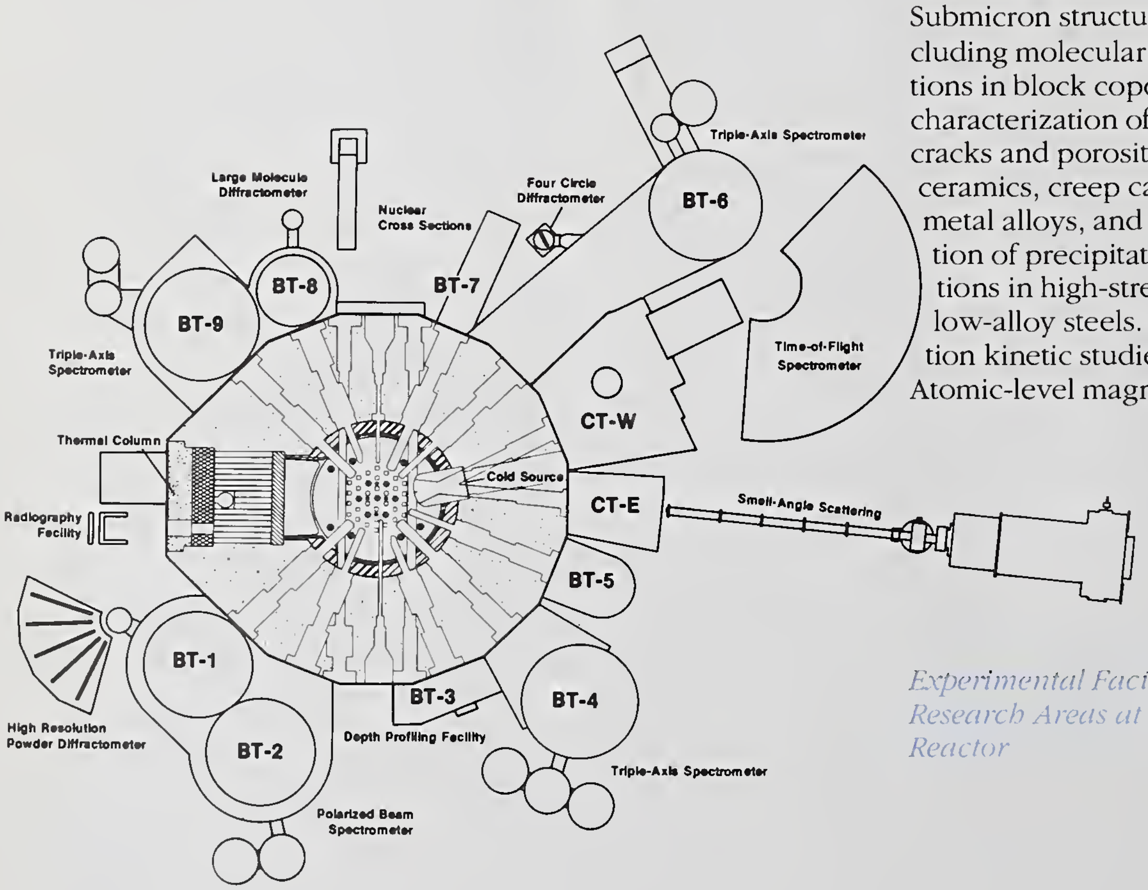
Element Analysis. Neutron activation analysis method development; applications to studies in environmental chemistry, nutrition, biomedicine, and energy systems. Neutron capture prompt gamma activation analysis method development.

Availability:

There are 25 experimental facilities at the reactor providing roughly 125,000 instrument hours per year to approximately 300 users. The users of the facilities represent 17 NIST divisions and offices, 16 other federal agencies, and approximately 50 university and industrial laboratories. Collaborative programs are arranged through NIST staff. Proposals for collaborative or independent use of the facility are reviewed by a committee which examines the merit and conditions of each application.

Contact:

Dr. Robert S. Carter, A106 Reactor Building, NIST, Gaithersburg, MD 20899, 301/975-6210.



Experimental Facilities and Research Areas at the NIST Reactor

Neutron Depth Profiling Facility

The neutron depth profiling (NDP) facility at the National Institute of Standards and Technology uses a neutron beam for nondestructive evaluation of elemental depth distributions in materials. Working with the Institute's 20-MW nuclear reactor, researchers use the technique to provide concentration profiles for characterizing the near-surface regime of semiconductors, metals, glasses, and polymers to depths of several micrometers. The facility uses filters and collimators to produce a high-quality neutron beam with good thermal neutron intensity and minimum contamination with fast neutrons and gamma rays. An aluminum target chamber is used to contain the samples in a vacuum, and a full array of electronic components is available for data acquisition and analysis.

Capabilities:

With the thermal neutron beam provided by the reactor, depth profiling can be carried out with sensitivities approaching 10^{13} atoms/cm^2. The method is not destructive to the sample and produces negligible radioactivation and energy deposition in the sample. A single analysis produces a profile typically 5 to 20 µm deep with a resolution of better than 30 nm, which is limited at present by the energy resolution of the surface barrier detectors used. Once calibrated with the appropriate elemental standard, the concentration scale is fixed independently of the sample composition. The depth scale is monotonically related to the energy scale by means of the charged particle stopping power. Elements that do not produce charged particles under thermal neutron irradiation contribute no interference.

Applications:

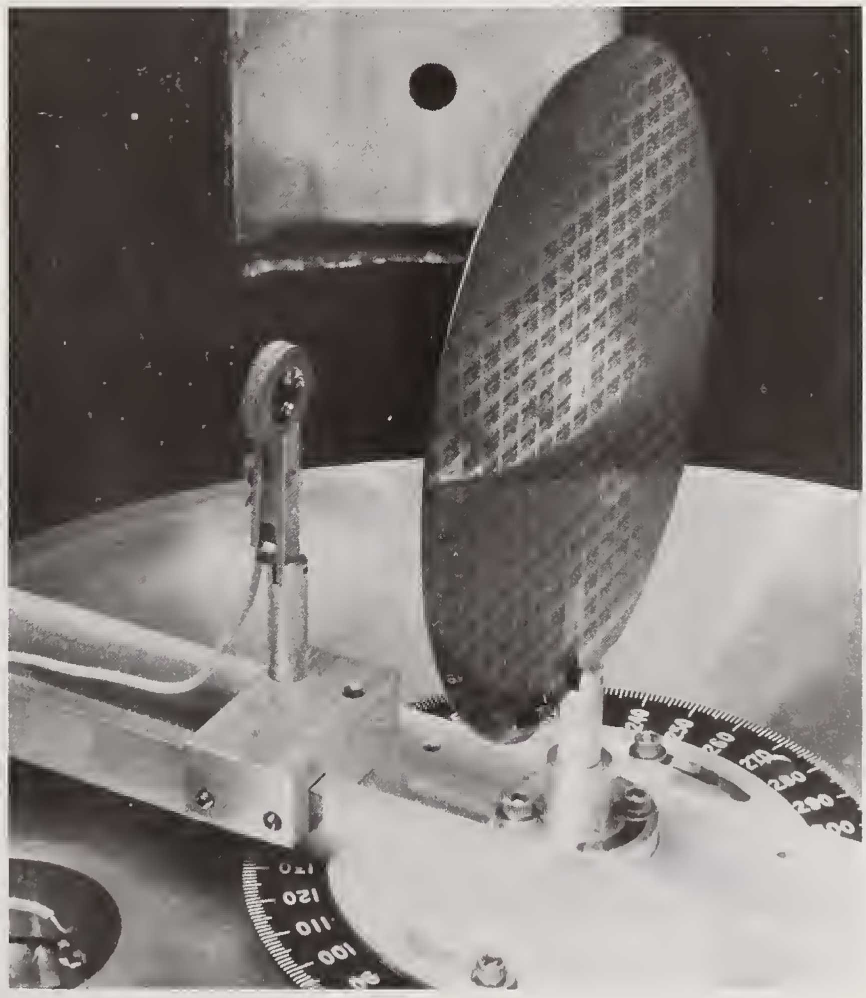
Some of the many applications of NDP include range measurements for boron implanted in Si, GaAs, and MCT; observations on near-surface boron in glasses; lithium concentration profiles in lithium niobates and aluminum alloys; measurement of helium release in single-crystal nickel to investigate the He-trapping phenomena; and measurement of high-dose nitrogen implants in steels.

Availability:

The facility is available to qualified researchers on an independent or collaborative basis with NIST staff.

Contact:

Dr. R. Greg Downing, B125 Reactor Building, NIST, Gaithersburg, MD 20899, 301/975-6286.



Sample Under Test at the Neutron Depth Profiling Facility

Small-Angle Neutron Scattering Facility

Small-angle neutron scattering (SANS) is a technique in which a highly collimated beam of low-energy (long wavelength) neutrons is used to probe the structure of materials on a size scale from roughly 1 to 100 nm. The small-angle diffraction patterns produced by structural features in this size regime—for example, by small precipitates or cavities in metal alloys, by micropores or cracks in ceramics, or by polymers or biological macromolecules—can be analyzed to yield important information about the size and shape of the scattering centers as well as their size distribution, surface area, and number density. In contrast to a complementary technique such as electron microscopy, a relatively large volume (up to about 1 cc) of material is examined in a SANS measurement. As a result, the information obtained represents statistical averages which are characteristic of the bulk material and which are related to bulk properties.

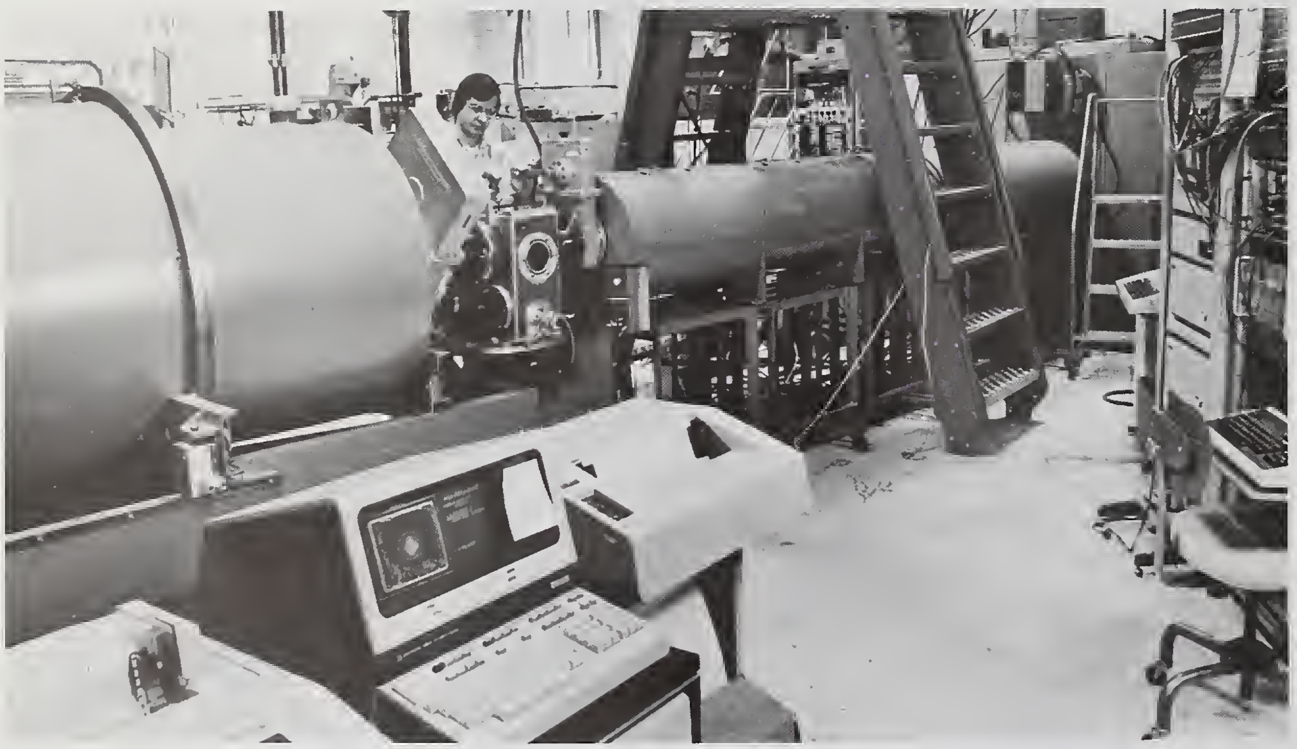
Capabilities:

The SANS spectrometer at the National Institute of Standards and Technology reactor utilizes a variable speed velocity selector to provide a beam whose wavelength is continuously tunable from 0.5 to 1.2 nm. Several choices of pinhole beam collimation are available, including a unique converging beam system which provides the instrument's best angular resolution (1.6 milliradians). Apparatus is available for maintaining samples at temperatures from 4 to 700 K and in magnetic fields up to 15 kilogauss.

For measurements at near ambient temperatures (0 to 80 °C), a multispecimen sample stage is used to change samples automatically under computer control. The neutron detector is a large (65 by 65 cm^2), two-dimensional, position-sensitive proportional counter which, in most cases, enables an entire scattering pattern to be recorded in a single measurement. The detector can, however, be rotated about the sample position to measure scattering at larger angles when necessary. An interactive color graphics terminal is used for imaging and analyzing completed data sets. Computer software is available for many forms of routine data analysis and model fitting.

Applications:

SANS is becoming an increasingly important tool in materials science and is used, for example, to study the kinetics and morphology of precipitate growth in high-strength alloys, to measure molecular conformation of polymers and



Small-Angle Neutron Scattering Facility biological macromolecular complexes, to detect and quantify early stage creep and fatigue damage in metals and ceramics, and to study the magnetic microstructure of new crystalline and amorphous magnetic materials. In many of these applications, especially those involving polymers, biology, and magnetism, the structural information provided by SANS cannot be obtained by any other technique.

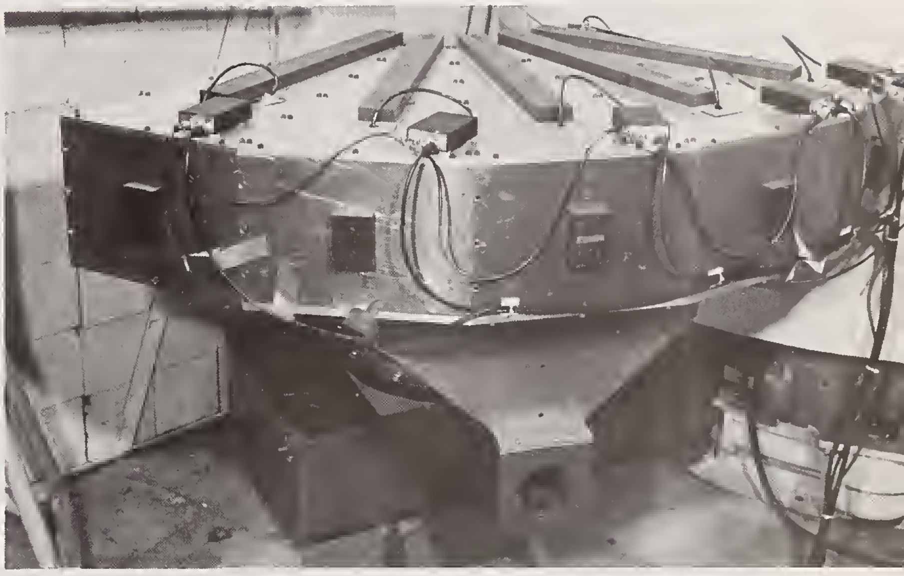
Availability:
The SANS facility is heavily utilized by NIST staff and others in industry, universities, and government. Proposals for collaborative or independent use of the facility are reviewed by a SANS scheduling committee, which examines the merit and conditions of each application.

Contact:
Dr. Charles J. Glinka, B106 Reactor Building, NIST, Gaithersburg MD 20899, 301/975-6242.

High-Resolution Neutron Powder Diffractometer

The high-resolution neutron powder diffractometer at the National Institute of Standards and Technology research reactor, with five detectors for simultaneous collection of data from different parts of the diffraction pattern, is used widely for studies of the structures of many important crystalline materials that are not available as large single crystals. Accurate structural information can be obtained at temperatures from 4 to 1200 K, which is often the key to understanding the properties of technologically important materials, including catalysts, magnetic materials, high-temperature alloys, minerals and ceramics, and ionic conductors.

Capabilities:
The NIST powder diffractometer system is designed to be "user-friendly" and highly flexible. For example, a variety of programs are available and documented, which allow the use of constrained refinement procedures to make use of known structural information on atomic or molecular units of the material being examined, along with advanced procedures for background, lineshape, and absorption corrections. Structural information can be analyzed at the NIST reactor using a high-speed, high-capacity superminicomputer or can be provided in convenient form on a floppy disk to be analyzed back at the user's own laboratory. A sophisticated technicolor graphics system is also available, with appropriate software to allow two- or three-dimensional displays, including stereographic projections of crystal structures of materials.



High-Resolution Neutron Powder Diffractometer

Availability:
This facility is available for use by industry, academia, and government on either a collaborative or independent basis under the supervision of NIST staff. The NIST powder diffractometer system is heavily utilized; projects are scheduled on a regular basis by an NIST committee.

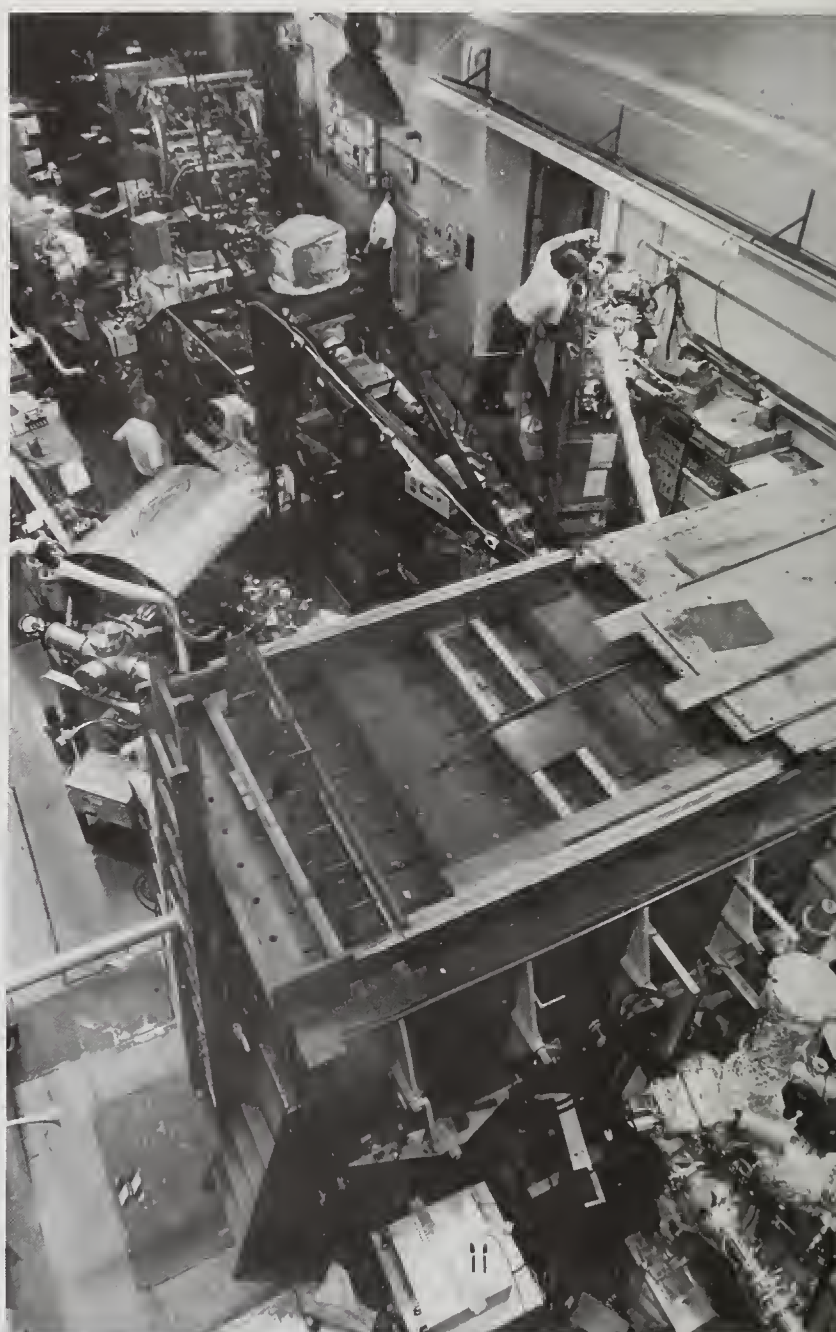
Contact:
Dr. Edward Prince, A106 Reactor Building, NIST, Gaithersburg, MD 20899, 301/975-6230.

Synchrotron Ultraviolet Radiation Facility-II

The Synchrotron Ultraviolet Radiation Facility-II (SURF-II) is a 300-MeV electron storage ring at the National Institute of Standards and Technology that radiates synchrotron radiation which is highly collimated, nearly linearly polarized, and of calculable intensity. Seven beamlines are available, and a user's program is in operation. SURF-II is well-suited for studies in: radiometry; atomic, molecular, biomolecular, and solid state physics; surface and materials science; electro-optics; and chemistry and radiation effects on matter.

Capabilities:

The typical storage ring electron beam current is 200 mA at 284 MeV. The photon intensity in the region 60 to 120 nm is about 3×10^{12} photons per second per milliradian of orbit for an instrumental resolution of 0.1 nm. Experiments can be made conveniently throughout the wavelength range 4 to 1000 nm, from the soft x-ray region to the infrared. A normal incidence, a grazing incidence, and several toroidal grating monochromators are available to disperse the radiation. A large, ultrahigh vacuum spectrometer calibration chamber, 1.2 m by 1.2 m by 2.5 m, is available for radiometric applications. A 6.65-m, normal-incidence vacuum spectrometer, with resolving power of about 200,000 is available on a



Synchrotron Ultraviolet Radiation Facility-II beamline dedicated to high-resolution vacuum ultraviolet radiation research.

Applications:
The continuous radiation from SURF-II is used as a national standard of spectral irradiance for radiometric applications and for fundamental research in: 1) atomic and molecular absorption spectroscopy; 2) optical properties of materials; 3) electron density of states in solids; 4) surface characterization; 5) photoelectron spectroscopy; 6) molecular kinetics and excitation and ionization dynamics; and 7) radiation interactions with matter (e.g., lithography, radiation damage, dosimetry, photobiology).

Availability:
Beam time on SURF-II is available to any qualified scientist provided beamline vacuum requirements are met and scheduling arrangements can be made. Proposals should be submitted for NIST review at least 2 months before use of the facility is desired. Informal contact is also encouraged.

Contact:
Dr. Robert P. Madden, A251 Physics Building, NIST, Gaithersburg, MD 20899, 301/975-3726.

Materials Science X-Ray Beamlines

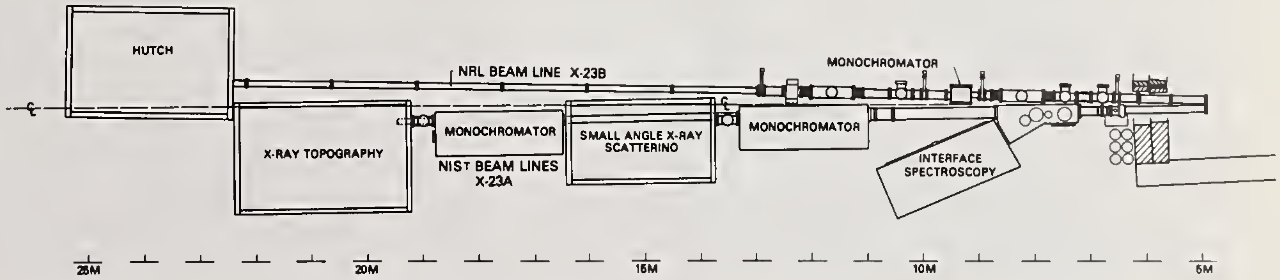
The NIST materials science x-ray beamlines at the National Synchrotron Light Source are used for advanced microstructure characterization of materials and for the performance of such measurements in real time. The spectral range and small source size of the radiation, combined with the high-resolution x-ray optics and dedicated instrumentation, make possible a large variety of measurements in x-ray topography, high-resolution microradiography, and surface and interface science.

Capabilities:
Experiments can be carried out in the photon energy range from 5 to 30 KeV. An energy durable monochromator provides a broad (3 cm x 3 cm) and parallel (several arc seconds) beam for high-resolution x-ray topography. A companion energy tunable x-ray image magnifier system can be used for the real-time observation and recording of microstructures down to 1 μm. Near-edge and extended absorption fine structure spectra can be taken using the monochromator in a scanning mode.

Applications:
The radiation from the materials science x-ray beamlines is used: to perform structure determination measurements on disordered materials and ultrathin films; for the nondestructive evaluation of imperfections and strains in materials; for the microstructure characterization of high-technology single crystals; for ultra-sensitive trace element detection; and for real-time microradiography experiments.

Availability:
Beam time on the materials science x-ray beamlines is available to any qualified scientist provided that beamline safety requirements are met and scheduling arrangements can be made. Proposals should be submitted to NIST and the National Synchrotron Light Source with ample lead-time before use of the facility is desired.

Contact:
Dr. Masao Kuriyama, A163 Materials Building, NIST, Gaithersburg, MD 20899, 301/975-5974.



Materials Science X-ray Beamlines at NSLS

Magnetic Microstructure Measurement Facility

The magnetic microstructure of materials can be measured with a very high spatial resolution by a technique called Scanning Electron Microscopy with Polarization Analysis (SEMPA). An ultra-high-vacuum electron microscope has been modified so that secondary electrons from the sample can be analyzed for their electron spin polarization. This allows for a measurement of the surface magnetism with moments both in the plane, and perpendicular to the plane, of the sample.

Capability:

SEMPA allows the simultaneous observation of surface microstructure and surface magnetic domains at a resolution of 0.1 μm, using an innovative, extremely compact electron spin detector invented at NIST.

Applications:

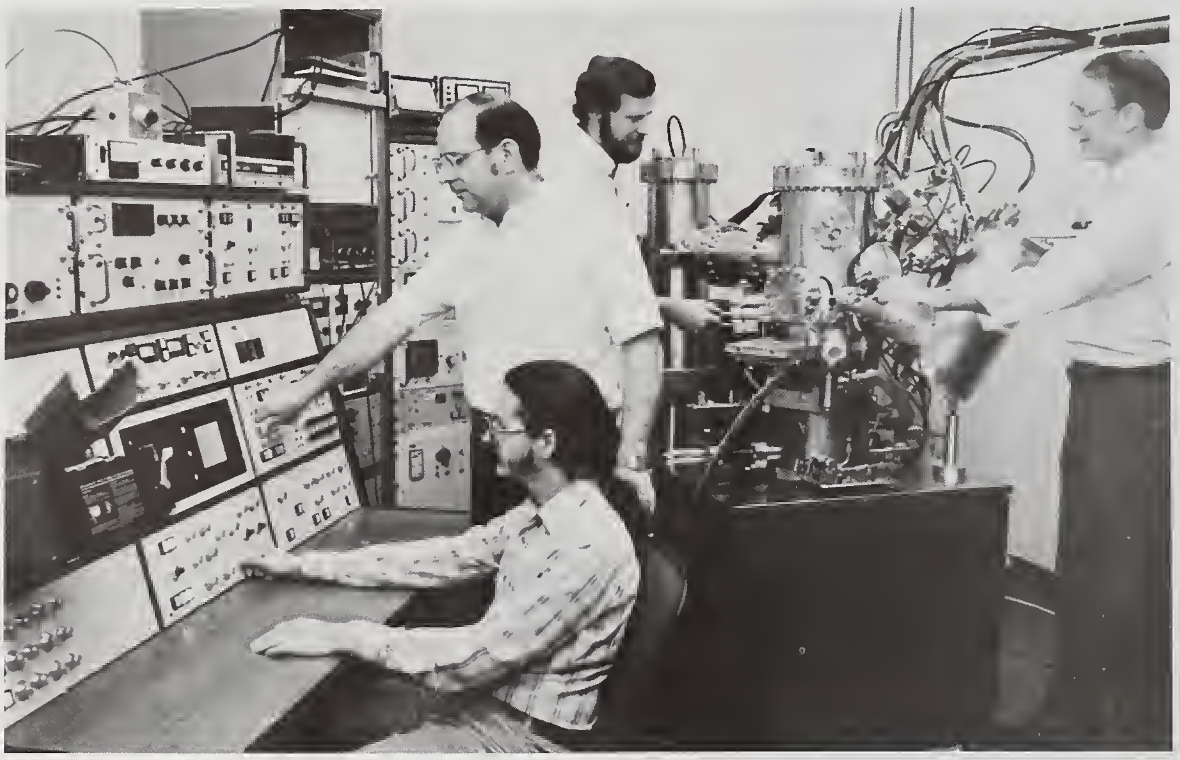
This unique measurement facility can be used for research in magnetic thin films, high-coercivity magnetic materials, high-density magnetic storage media, and other advanced magnetic materials.

Availability:

These facilities are available for collaborative research by NIST and outside scientists in areas of mutual interest and benefit on a time-available basis.

Contact:

Dr. Robert J. Celotta, B206 Metrology Building, NIST, Gaithersburg, MD 20899, 301/975-3710.



Magnetic Microstructure Measurement Facility

Small-Angle X-Ray Scattering Facility

Small-angle x-ray scattering (SAXS) is a technique in which a highly collimated beam of x rays (wavelength range 0.7 to 3 angstroms) is used to probe the structure of materials on the size scale of 0.1 to 100 nm. Materials exhibiting structure in this size range include polymers, biological macromolecules, ceramics, metals, and alloys. The small-angle scattering patterns can be analyzed to characterize the size and shape of the scattering centers as well as their spatial distribution and surface area. Data obtained from these experiments are complementary to data obtained from other diffraction studies and from morphological studies using electron microscopy.

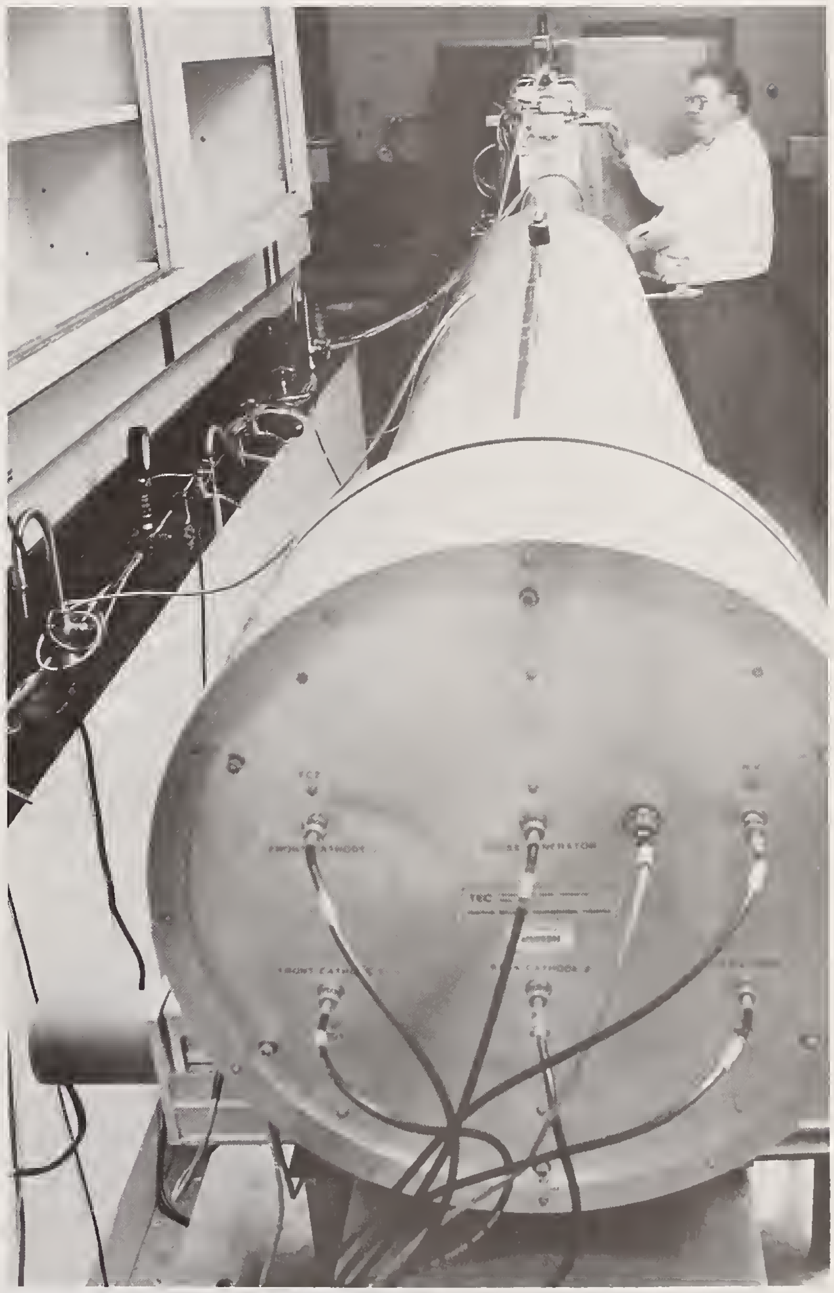
Capabilities:
The NIST 10-meter SAXS camera uses a 12-kW rotating anode x-ray generator as a source of x rays. The target is usually copper $\lambda(K\alpha) = 1.54$, but additional wavelengths are available. The collimation path is defined so as to permit a 10^{-2} nm^{-1} resolution in reciprocal space at the surface of a two-dimensional position-sensitive proportional detector. The collimation path and the scattered beam path are evacuated and all elements of vacuum operation, x-ray optical configuration, sample selection, and calibration are computer controlled. Image data are collected by a minicomputer and an associated VAX/730 computer supports a complete repertory of software for displaying, analyzing, and modeling the results.

Sample chambers are being developed for measurements at high temperatures and to deform specimens during measurement.

Applications:
The SAXS technique is used to study molecular conformation, microphase domain structures, crystallization phenomena, network formation, craze initiation, void distribution, and similar phenomena resulting from fluctuations in electron density within a material. Such studies are currently of broad interest in all areas of materials science.

Availability:
This facility is operated by members of the NIST staff in support of their active research program in polymeric materials. It is available for use by researchers from industry, academia, and other government agencies on either a collaborative or independent basis.

Contact:
Dr. John D. Barnes, B210 Polymer Building, NIST, Gaithersburg, MD 20899, 301/975-6786.



Small-Angle X-ray Scattering Facility

Ultra-Clean Ceramic Processing Laboratory

The ultra-clean ceramic processing laboratory at the National Institute of Standards and Technology is a specially designed facility for the production and densification of advanced ceramic powders under conditions of ultra-controlled chemical composition. The facility is used to elucidate the influence of controlled chemical composition on all stages of advanced ceramic processing, particularly sintering science, and on the subsequent physical properties of such tailored advanced ceramics. Chemical composition is monitored at various stages of the processing route by neutron activation analysis (gamma-ray spectroscopy) at the NIST research reactor or by induction coupled plasma spectroscopy. The modular design of the laboratory is such that multi-user operations can easily be performed with a minimum of cross-contamination.

Ultra-Clean Ceramic Processing Laboratory

Capabilities:

The NIST ultra-clean ceramic processing laboratory was specially designed for the production and processing of advanced ceramic powders and samples with controlled levels of impurities and dopants. The predominant feature of the 37-m^2 laboratory is the eight central laminar-flow work areas. These eight individual modules provide a total of 7.5 m^2 of laminar-flow work area, which is equivalent to class 10 or better. The modules are isolated one from another to permit multi-user operations with a minimum of cross-contamination. The laboratory has an additional 1.5 m^2 of laminar flow exhaust hood work area and a standard chemical hood. The laboratory water supply is deionized water and further purification is available from a quartz still. Facilities are available in the laboratory for the calcination and compaction of ceramic powders, as well as subsequent sintering under "clean" conditions.

Applications:

One problem that hinders the widespread use of advanced ceramics is their lack of reproducibility during processing. A major factor contributing to this irreproducibility is the sensitivity of the microstructure and properties of these high-technology ceramic materials to low levels of impurities. Because of this sensitivity, correlating changes in performance with changes in processing has been difficult due to concomitant changes in composition. By producing and processing ceramics under ultra-clean room conditions by chemical routes, this variability in composition can be controlled, thus allowing the influence of other processing variables (e.g., particle size and shape, agglomeration, compaction method, and atmosphere) to be analyzed. Such control also allows the influence of trace levels of dopants to be studied in a more reliable and systematic way. Such studies will lead to better understanding of microstructural evolution during processing, which, in conjunction with other ongoing efforts for producing unique compositions and phases, can lead to new advanced ceramic materials with unique microstructures and properties.

Availability:

This facility is available for use by industry, academia, and government on either a collaborative basis or an independent basis under the supervision of the NIST staff. The design of the laboratory is such that several different projects can be conducted simultaneously with minimal cross contamination. This allows the facility to be used concurrently by several researchers. Accordingly, industrial use of this laboratory is being sought for collaborative research with NIST or feasibility studies on their part.

Contact:

Dr. John E. Blendell or Dr. Edwin R. Fuller, Jr., A258 Materials Building, NIST, Gaithersburg, MD 20899, 301/975-5796 or 301/975-5795.

Sample Preparation in the Powder Characterization Laboratory

Powder Characterization Laboratory

The NIST powder characterization laboratory is equipped with specialized instruments to generate, fractionate, and make physical property measurements on powdered materials. Measurements can be made of particle size distributions, surface area, and zeta potential.

Capabilities:

Particle Generation. The particle generation equipment includes a solution atomizer system which generates polydisperse aerosols in the size range 0.01 to 1 µm; a vibrating orifice system which forms monodisperse aerosols in the size range 0.5 to 100 µm; spray dryers used to form spherical flowable powders; and a micro-jet mill for grinding powders to submicron size without contamination.

Particle Sizing. Powder size distributions are determined using a photon correlation spectrometer for average size of suspended particles in the range 0.003 to 3 µm; an x-ray sedigraph for size distributions of powders in the range 0.1 to 100 µm; centrifugal photosedimentation apparatus for size distributions of particles in the range 0.01 to 10 µm; and an electrostatic classifier for particles in the 0.003 to 1.0 µm range. Size measurement of particles by direct examination with a scanning electron microscope/image analysis system is available on a collaborative basis.

Fractionation. Three riffle splitters are available for division of powder samples into representative subsamples; a sonic sifter classifies by sieving using electroformed sieves

and a vibrating column of air; a bulk particle classifier separates large powder samples into narrow size fractions in the 1.0 to 35 μm range; and an electrostatic classifier selects out a narrow size range of particles from a polydisperse sample with particles in the 0.005 to 0.3 μm range.

Physical Property Measurements. An electrophoresis meter is used to measure the zeta potential of particles in a dispersant; a multipoint BET unit determines specific surface area of powders; and a mercury porosimeter can measure pore size distributions in the 0.003 to 300 μm range. Additional equipment includes: HEPA filters to remove particulates from air entering the laboratory, sterile benches where the filtered laboratory air is further cleaned through HEPA filters, microbalances, and a controlled atmosphere/humidity glove box for powder handling.

Availability:

These laboratory facilities are primarily used in support of NIST research programs using ceramic powders. They are also available for collaborative or independent work by qualified government, industry, or university personnel with preference given to projects related to ceramics research.

Contact:

Dr. Alan L. Dragoo, A258 Materials Building, NIST, Gaithersburg, MD 20899, 301/975-5785.

Metals Processing Laboratory

The metals processing laboratory at the National Institute of Standards and Technology contains special facilities for the production of rapidly solidified alloys, including equipment for inert gas atomization and electrohydrodynamic atomization to produce rapidly solidified alloy powders, melt spinning to produce rapidly solidified alloy ribbons, and electron beam surface melting to produce rapidly solidified surface layers. Hot isostatic pressing equipment is available for consolidation of the alloy powders.

Capabilities:

Inert Gas Atomization. The inert gas atomization system can be used to produce up to 25 kg of rapidly solidified alloy powder per batch while maintaining an inert environment throughout the atomizing and powder handling process. High-pressure inert gas (Ar, He, or Ar-He mixtures) impinging on a liquid metal stream breaks up the liquid into small droplets which solidify rapidly. Cooling rates are up to 10^5 K/s. The atomized powder, entrained in the inert gas flow, is collected in removable, vacuum-tight canisters.

Electrohydrodynamic Atomization. In the electrohydrodynamic atomization system, a liquid metal stream is injected into a strong electric field. The field causes the stream to disintegrate into droplets which solidify rapidly to produce extremely fine (<1 μm diameter) alloy powder. Powder produced by this process is well-suited for studying solidification dynamics. As the system is presently configured, small quantities for microscopic examination can be produced from alloys with melting points up to 900 °C.

Melt Spinning. Melt-spinning techniques can be used to produce rapidly solidified alloys in ribbon form. Because of the high cooling rates (up to 10^6 K/s) with this method, amorphous alloys as well as crystalline alloys can be produced. Ribbons up to 3 mm wide and up to 0.05 mm thick can be produced in quantities of several grams per batch. Materials with a wide range of melting points, from aluminum alloys to super-alloys, have been produced.

Electron-Beam Surface Melting. An electron-beam system which provides surface melting and subsequent rapid resolidification of surface layers can be operated in either a pulsed or continuous mode. The electron beam can be focused to a spot less than 1 mm in diameter and deflected at frequencies up to 5 kHz.

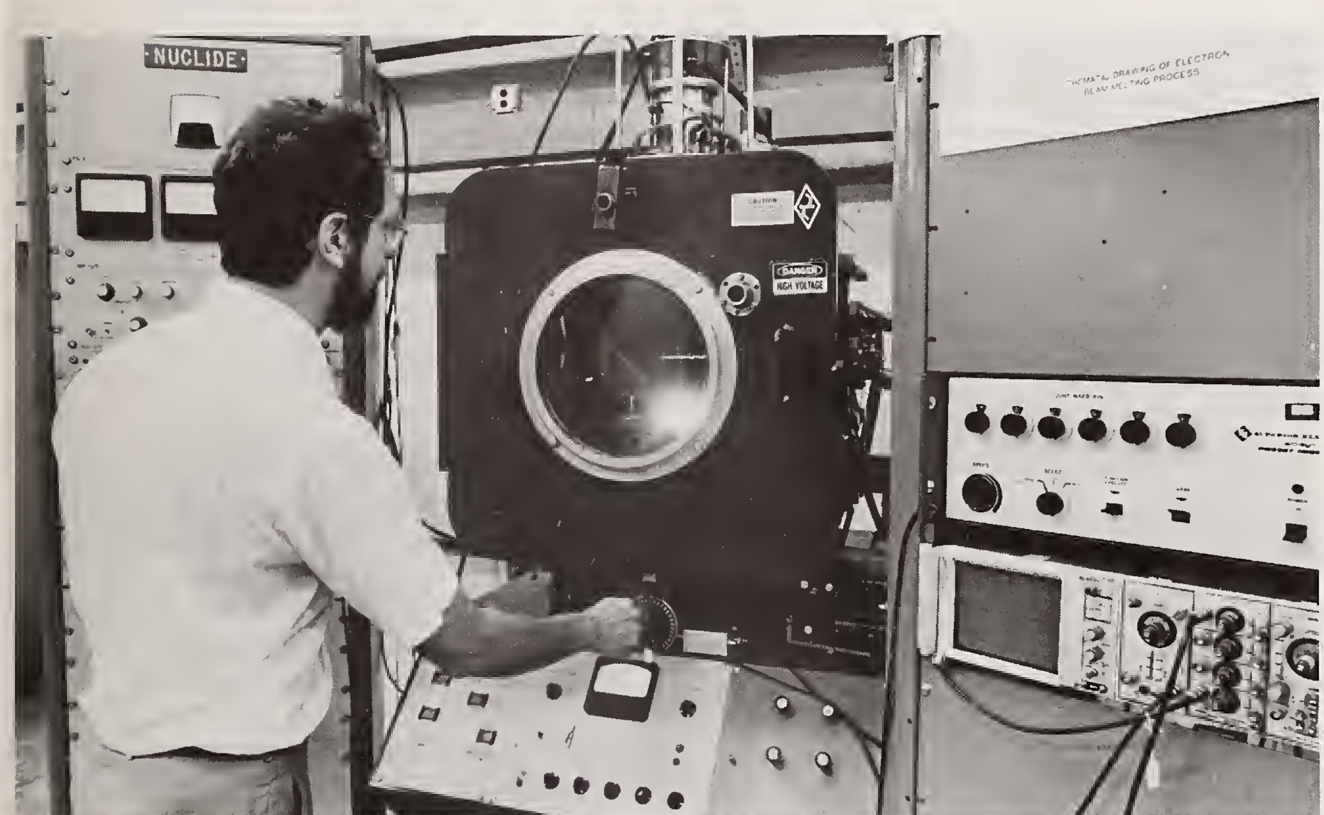
Hot Isostatic Press. A hot isostatic press (HIP) with microprocessor control of the temperature-pressure-time cycle is available for consolidation of powder or compacted powder shapes. The HIP has a cylindrical working volume 15 cm in diameter and 30 cm high. The maximum working pressure is 207 MPa. The molybdenum furnace has a maximum heating rate of 35 K/min and is capable of maintaining 1500 °C.

Availability:

These facilities are designed to produce alloy research samples which are difficult otherwise for users to obtain. Typically, industrial companies or universities send workers to NIST to participate in preparing alloys of special industrial and scientific interest for further analyses in their home laboratories and to collaborate with NIST scientists in investigations of generic relationships between processing conditions and resulting alloy microstructures and properties.

Contact:

Dr. John R. Manning, A153 Materials Building, NIST, Gaithersburg, MD 20899, 301/975-6157.



Electron-Beam Surface Melting Apparatus in the Metals Processing Laboratory

Melt Spinning Apparatus in the Metals Processing Laboratory

Mechanical Behavior Laboratories

Mechanical property measurement facilities at the National Institute of Standards and Technology permit characterization of all mechanical properties over a wide range of force levels and temperatures. Special capabilities include measurement of strength and toughness at temperatures from 4 to 2800 K and tests of wide plates or special structural elements at force levels of 50 MN (5000 metric tons) in compression and 25 MN (2500 metric tons) in tension.

Capabilities:

Conventional mechanical property measurements including yield and ultimate strengths, elongation, and reduction of area can be done at temperatures ranging from 4 K, produced by immersion of the specimen in liquid helium in cryostatted test apparatus specially designed for this purpose, to 2800 K, produced by testing in a vacuum furnace heated by tungsten elements. Equipment for measurement of fracture toughness over the same temperature range is in use. Material fatigue resistance can be characterized in a variety of ways, including fatigue crack growth, load- and strain-controlled, random-load, or conventional rotating beam, at temperatures from 4 K to 600 K. Narrow- and wide-plate behavior, including crack arrest characteristics, is studied using computer-assisted data acquisition and reduction for handling of data from strain gages (up to 75 have been used), capacitance and strain-gage extensometers, and full-field video-optical strain data. Photoelastic and moire techniques are used to produce images of strain fields. High-speed digital oscilloscopes record the strain patterns produced by the passage of cracks moving at hundreds of meters per second in crack arrest tests. Special test requirements including dynamic tear, drop weight, torsion, and impact can be met using existing facilities. Complete metallographic and hardness characterizations of specimen materials are available.

Fracture Testing in the Mechanical Behavior Laboratory

Availability:

The high-force-capacity mechanical testing machine has a force capacity of 50 MN (5000 metric tons) in compression and 25 MN (2500 metric tons) in tension. Servo-hydraulic tension-compression machines are available in a range of load capacities and actuator travel rates; the maximum load capacity of 4 MN (400 metric tons) and the maximum displacement rate is 50 cm/s. The smaller machines are routinely used for measuring fracture and fatigue properties in liquid helium. Two screw-driven tensile machines have capacities up to 100 kN (10 metric tons) for tensile testing in liquid helium. These facilities are available for guest researchers or collaborative programs. NIST routinely performs research on these facilities for outside sponsors.

Contact:

Dr. Richard P. Reed, 1601 Cryogenics Building, NIST, Boulder, CO 80303, 303/497-3870.

Toxic Chemicals Handling Laboratory

Toxic Chemicals Handling Laboratory

The toxic chemicals handling laboratory at the National Institute of Standards and Technology is used to store, handle, and analyze organic compounds that are extremely toxic and/or possess undesirable biological activity.

The laboratory was designed through the joint efforts of scientists from NIST and a private architectural and engineering firm. Its features offer special protection for those using the laboratory. The facility was specially designed and is used to allow scientists to perform research that involves the characterization or analysis of toxic or mutagenic organic materials in a safe manner. The laboratory is equipped with facilities for weighing, sample storage, sample preparation (extractions, etc.), and gas and liquid chromatographic analyses.

Capabilities:

Laboratory Work Space. The laboratory has approximately 10 m of bench space for sample preparation and other analytical activities. The air throughout the working area in the laboratory is recirculated at a rate of 225 m^3/min (~8000 ft^3/min) through charcoal filters to remove organic vapors and HEPA filters to remove particulate material. The air flow is directed so that scientists using the facility are continuously bathed with clean air. The air supply to the laboratory is ~11m^3/min less than the exhaust, thereby preventing diffusion of possibly toxic vapors from the facility into the hall and adjacent laboratories.

Cabinet Space. The laboratory has 5 m^2 of actively vented cabinet space for storage of toxic chemicals. Air flowing from the storage areas is charcoal filtered and totally exhausted to the outside.

Safety Hoods. The laboratory is equipped with two air barrier fume hoods for manipulations of pure chemicals (including weighing) or concentrated solutions. All air entering the hoods is exhausted to the outside after charcoal filtration.

Other. The laboratory also has shower facilities.

Availability:

The laboratory and its facilities can be shared with qualified staff from NIST, other government agencies, universities, and industry. Since space is limited, preference will be given to NIST users and to projects that are related to NIST interests. Due to the toxic nature of the chemicals involved in various experiments and stored in the facility, all projects will be monitored by NIST personnel.

Contact:

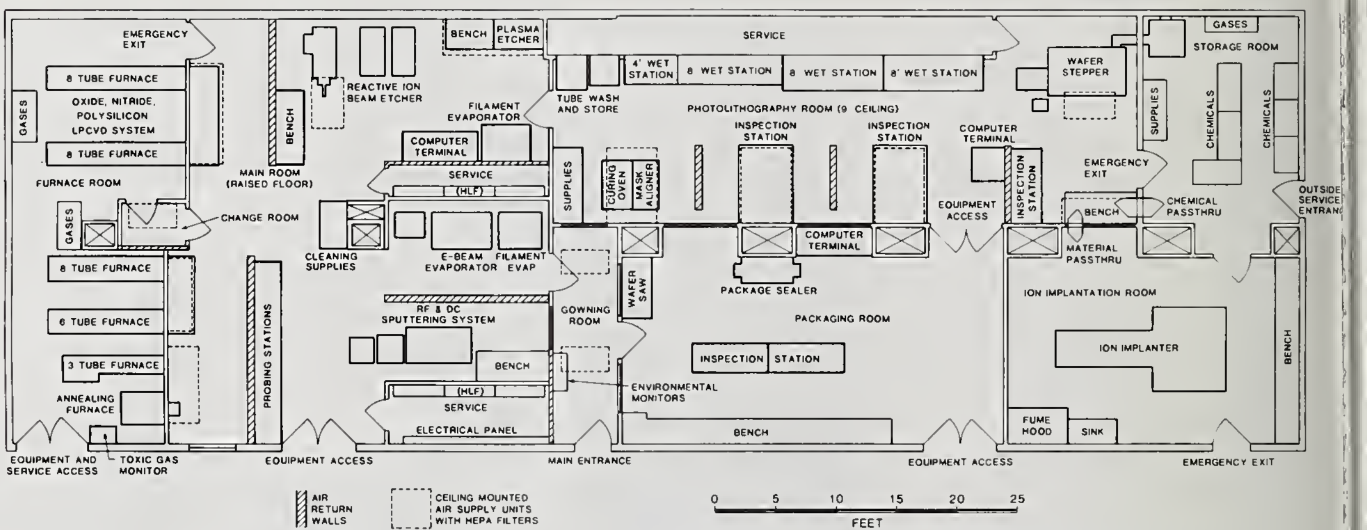
Dr. Willie E. May, A113
Chemistry Building, NIST,
Gaithersburg, MD 20899,
301/975-3108.

Semiconductor Processing Research Laboratory

As integrated circuit sizes increase to more than 1 cm^2 and feature sizes within the circuits decrease to less than 1 μm, critical demands are placed on the measurement capability required to control and monitor the fabrication successfully. To meet the demand, research to develop state-of-the-art measurement procedures for microelectronics manufacturing is a focus of the Semiconductor Program at the National Institute of Standards and Technology.

The semiconductor processing research laboratory provides a quality physical environment for a broad variety of research in semiconductor microelectronics, as well as in other areas of physics, chemistry, and materials research. The laboratory facilities are utilized for projects that address many aspects of semiconductor materials and processes, including process control and metrology, materials characterization, and the use of integrated circuit materials and processes for novel applications.

The laboratory complex occupies about 4,000 square feet, approximately half of which is composed of clean rooms. Within the clean rooms, work areas are maintained at class 10 or better. The facility is designed so that the work areas can be easily modified to accommodate the frequent equipment and other changes required by research.



Semiconductor Processing Research Laboratory

Capabilities:

The semiconductor processing research laboratory has a complete capability for integrated circuit fabrication. The principal processing and analytical equipment are listed below. The capabilities are expanded and improved continuously to meet the technological challenges.

Diffusion, oxidation, and annealing. Six furnace tubes for up to 75-mm diameter wafers and nine tubes for up to 100-mm diameter wafers.

Photolithography. Research mask aligner (proximity and contact) for wafers up to 100 mm in diameter and irregularly shaped samples and 10x direct-step-on wafer system for 75-mm diameter wafers. Photoresist spin coating and developing and related chemical processing, including oxygen plasma stripping.

Film deposition. Low-pressure chemical vapor deposition systems for depositing silicon nitride, polysilicon, and low-temperature silicon dioxide. Rf and dc vacuum sputtering of metals and dielectrics. Electron beam and hot filament vacuum evaporation of metals.

Etching. Wet and dry etching processes. Reactive ion beam etcher capable of ion milling and chemical etching with gases such as freon, sulfur hexafluoride, oxygen, and chlorine.

Ion implantation. Multipurpose 200-KeV ion implanter.

Analytical measurements. Thin-film reflectometry and other thickness measurements, optical microscopy, and grooving and staining. Automated and manual probe stations for current-voltage measurements and capacitance measurements as a function of voltage, frequency, and time.

Applications:

Small quantities of specialized semiconductor test specimens, experimental samples, prototype devices, and processed materials can be produced. Also, the processes and processing equipment can be monitored during operation to study the process chemistry and physics. The effects of variations in operating conditions and process gases and chemical purities can be investigated. The research is performed under well-controlled conditions.

Because the work is of a research nature, the laboratory is not designed to produce large-scale integrated circuits or similar complex structures. Rather, the breadth and flexibility of the laboratory is primarily to support the varied types of projects performed.

Currently active research projects address many aspects of microelectronic processing steps and materials. A few examples are: metal-oxide-semiconductor measurements; metal-semiconductor specific contact resistivity; uniformity of resistivity, ion implanted dopant density, surface potential, and interface state density; characterization of deposited insulating films on silicon carbide; ionization and activation of ion implanted species in semiconductors as a function of annealing temperature; electrical techniques for dopant profiling and leakage current measurements; and processing effects on silicon-on-insulator materials.

Availability:

The staff of the semiconductor processing research laboratory welcome collaborative research projects that are consistent with the research goals of the NIST Semiconductor Program. Work is performed in cooperation with the technical staff of the laboratory.

The most productive arrangement begins with the development of a research plan that includes specific goals. The commitment of knowledgeable researchers to work closely with NIST staff and the provision of equipment and other needed resources is required. For safety, because there are hazardous materials present, laboratory staff must supervise closely all research activities.

Contact:

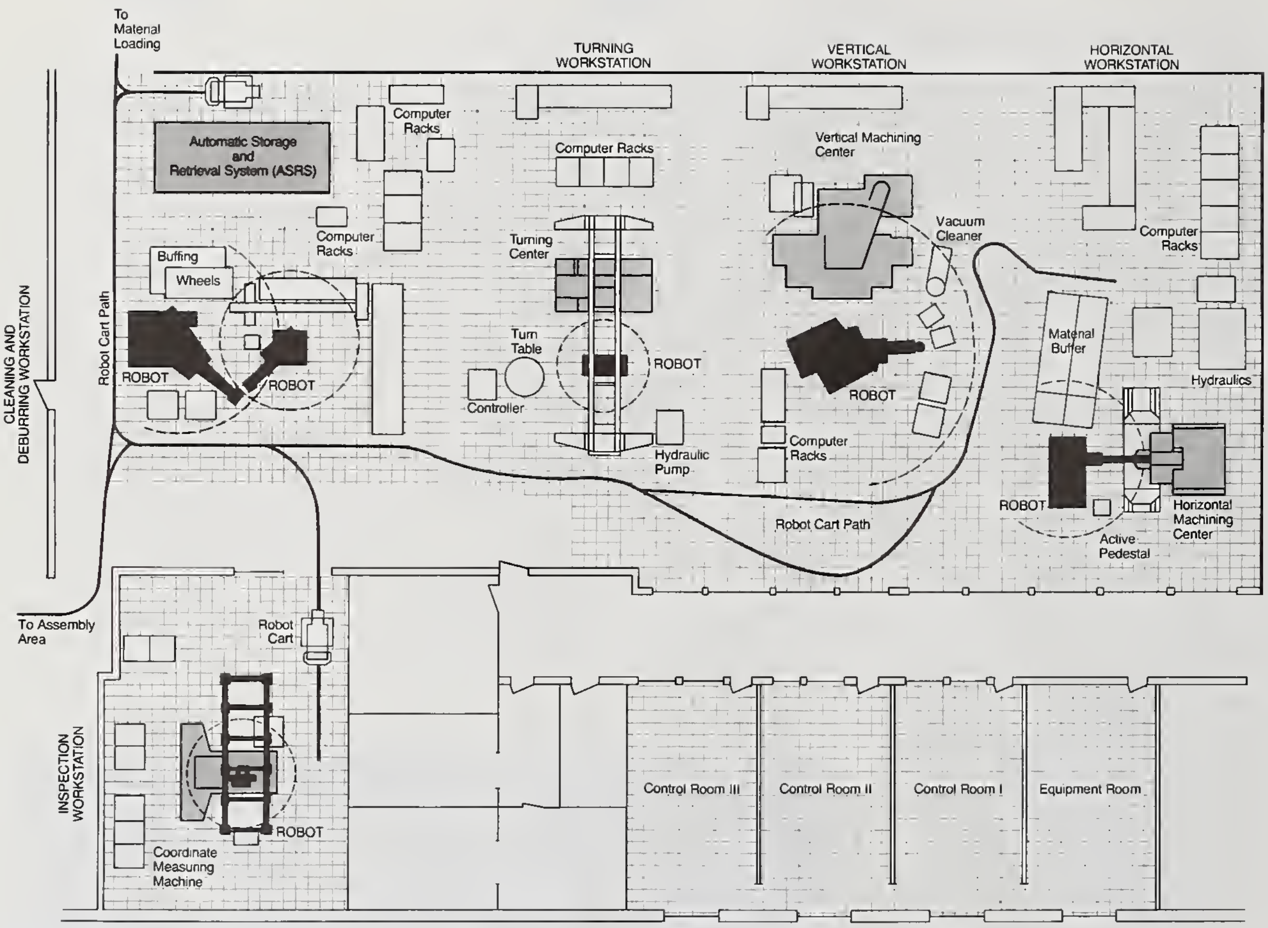
Dr. Donald Novotny, A331 Technology Building, NIST, Gaithersburg, MD 20899, 301/975-2699.

Automated Manufacturing Research Facility

The Automated Manufacturing Research Facility (AMRF) at the National Institute of Standards and Technology is a major national laboratory for technical work related to interfaces and standards for the next generation of computer-automated manufacturing. The facility, begun in 1981, was put into full operation in 1986. A companion installation, located in the adjacent instrument shop, is planned as a state-of-the-art production facility, making use of the best technology from the AMRF which is production ready.

The workstations of the AMRF are being used in active

Programming Work Area at the Horizontal Workstation in the AMRF



Automated Manufacturing Research Facility

research programs by NIST researchers, industrial research associates, guest researchers, university personnel, and scientists and engineers from other government agencies.

Capabilities:

The facility currently supports research in machine tool and robot metrology, sensors and sensory processing, robot safety, robot control, software accuracy enhancement of machine tools, process planning and data preparation for machine tools and robots, parts routing and handling, real-time control of robots and aggregations of devices, workstation control, cell control, and materials handling control. It is particularly valuable for studies of interfaces between control modules and among data users. The AMRF is unique in the opportunities it provides for studies of an integrated system of significant size.

The facility consists of three machining centers, a coordinate measuring machine, and a cleaning and deburring station, each tended by an industrial robot and served by a materials handling system based on an automated wire-guided vehicle and an internal buffer storage system for tools, materials, and work in progress.

These devices are organized into workstations consisting of a major machine tool, its robot, a variety of sensors, and a workstation controller. Workstation activities are scheduled and coordinated by a cell controller. Two further control levels, providing long-range planning and scheduling as well as engineering services, are projected for implementation during 1988 and 1989. These levels house manufacturing data preparation functions of geometry modeling, process planning, NC programming, and robot off-line programming. Data, commands, and status information are handled over a network communications system employing a distributed data administration approach.

Availability:

By the nature of the problems addressed, the AMRF is generally best suited for research projects of an extended nature. Most fruitful work to date has involved a close working relationship with NIST which extends for 6 months to 1 year.

Contact:

Dr. Philip N. Nanzetta, B112 Metrology Building, NIST, Gaithersburg, MD 20899, 301/975-3414.

Near-Field Scanning Facility for Antenna Measurements

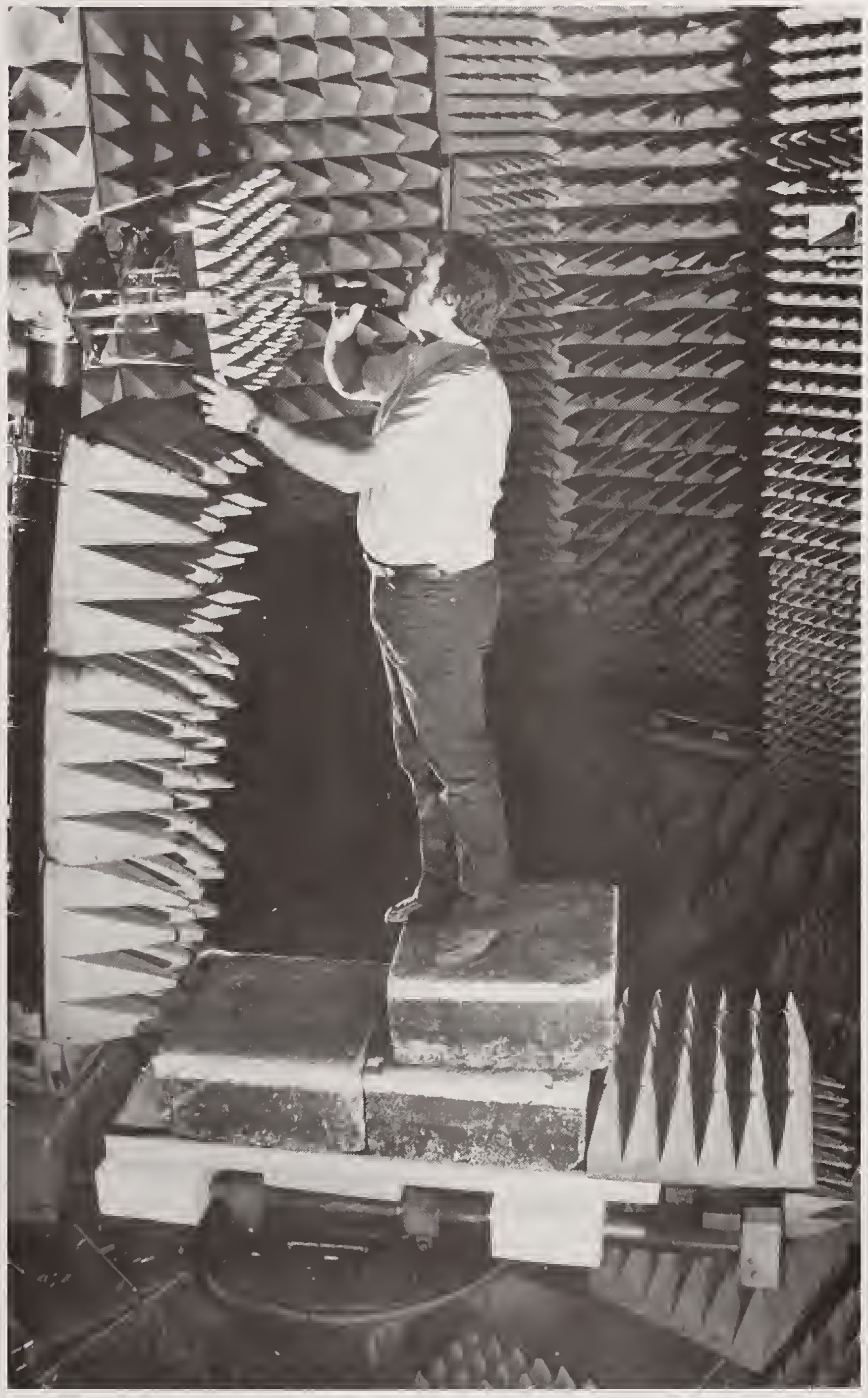
Capabilities:

The automated facility is designed to measure the near-zone phase and amplitude distributions of the fields radiated from an antenna under test. Mathematical transformations are then employed to calculate the desired antenna characteristics. Near-field data can be obtained over planar, cylindrical, and spherical surfaces, with the planar technique being the most popular. Efficient computer programs are available for processing the large quantities of data required.

When operated in the planar mode, the facility is capable of measuring over a 4.5-m by 4.5-m area with probe position errors of less than ±0.01 cm. Improved position accuracy is possible with further alignment, especially over smaller areas. Antennas with apertures up to about 3 m in diameter can be measured with a single scan and the facility has been used successfully over the frequency range 750 MHz to 75 GHz. The facility will be enlarged so that larger antennas can be measured by scanning in segments.

Applications:

Antenna Characteristics. The facility is used primarily for determining the gain, pattern, and polarization of antennas. Accuracies are typically ±0.15 dB for absolute gain and ±0.10 dB/dB for polarization axial ratio. Patterns can be obtained down to the −50 to −60 dB levels with side lobe accuracy typically about ±1.0 dB at the −40 dB level. (The exact uncertainties depend on the frequency, type, and size of antenna, etc.) The near-field data can also be used to compute near-field interactions (e.g., mutual coupling) of antennas and radiated field distributions in the near zone.



Near-Field Scanning Facility

Antenna Diagnostics. Near-field scanning is also a valuable tool for identifying problems and for achieving optimum performance of various types of antenna systems. It has, for example, been used to advantage in locating faulty elements in phased array antennas and for adjusting feed systems to obtain the proper illumination function at the main reflector. Phase contour plots of the near-field data can also be used to determine surface imperfections in reflectors used for antennas or compact ranges.

Probe Calibrations. A new spherical probe calibration facility is used as a far-field range for measuring the receiving characteristics of probes used to obtain near-field data. These measurements are required to determine the probe coefficients which, in turn, are used to calculate accurate, probe-corrected, far-field gain and pattern characteristics of an antenna.

Availability:

Two kinds of arrangements can be made to use this facility. NIST staff can perform specified tests or measurements on a reimbursable basis. In this case, the customer has no direct use of the facility; all measurements are performed by NIST staff and the customer is issued a test report. As an alternative, work may be performed on a cooperative basis with NIST staff. This arrangement permits the user the advantage of developing first-hand knowledge of the measurement processes, and the user is responsible in large part for the accuracy of test results. In either case, arrangements need to be made well in advance, and reimbursement is required for the facility use and time of NIST staff involved.

Contact:

Mr. Allen C. Newell, 4083 Radio Building, NIST, Boulder, CO 80303, 303/497-3743.

Mode-Stirred Chambers

Researchers at the National Institute of Standards and Technology have designed and constructed mode-stirred (reverberating) chambers that are available for use in performing radiated electromagnetic emissions and susceptibility (EME/S) measurements of electronic equipment and shielding effectiveness (SE) measurements of materials. A mode-stirred chamber is an electrically large (in terms of wavelength), high-quality (Q) cavity whose boundary conditions are varied by means of a rotating conductive tuner or stirrer. The time-averaged field inside such a cavity, when a sufficient number of modes are excited, is formed by uniformly distributed plane waves coming from all directions. This property causes the polarization of the field to vary randomly hence eliminating the need for, or the utility of, physical rotation of test objects in the field. A microwave oven is a simple example of a mode-stirred chamber without measurement support instrumentation.

Capabilities:

The mode-stirred chamber simulates near-field conditions for tests at frequencies from 200 MHz to 40 GHz. High-level test fields (up to 1000 V/m) can be generated efficiently over a large test volume in the chamber, or the chamber can be used to measure low-level radiated emissions (total radiated power down to −100 dBm) from equipment under test (EUT) with minor instrumentation changes. Equipment as large as 1.5 m x 2.0 m x 3.0 m can be tested.

Applications:

In addition to use for performing radiated emission or susceptibility measurements of electronic equipment, the mode-stirred chambers can be used to measure the shielding effectiveness of gasketing, composites, and other materials used for radio frequency shielding applications. The chambers can also be used for measuring the shielding effectiveness of wiring harnesses and electrical cables, connectors, and assemblies.

Limitations:

The usable lower frequency is limited by insufficient mode density, tuner effectiveness, and ability to uniformly excite all modes in the chamber. These factors are a function of both chamber geometry and size. Measurement uncertainties vary from ±10 dB at 200 MHz decreasing to ±4 dB from approximately 1.0 GHz to 18 GHz. Directional characteristics of an antenna or test equipment placed inside a mode-stirred chamber are lost, resulting in the need to estimate their free-space maximum gain as a function of frequency in order to correlate results obtained by open-field tests. However, tests can be performed cost effectively in a shielded environment, with sufficient accuracy to make these facilities very attractive for diagnostic testing and for use in minimizing the need for expensive testing in facilities such as anechoic chambers.

Availability:

Two mode-stirred chambers, a large (2.74 m x 3.05 m x 4.57 m) and a small (1.16 m x 1.425 m x 1.47 m), are available. NIST staff are available for collaborative programs or to advise and interpret measurement results. Independent testing can also be arranged.

Contact:

Dr. Motohisa Kanda, 4633 Radio Building, NIST, Boulder, CO 80303, 303/497-5320.

Outdoor Extrapolation Range for Antenna Measurements

Capabilities:

This unique facility was designed to perform accurate measurements of absolute gain and polarization of microwave antennas using the "Extrapolation Method" developed by the National Institute of Standards and Technology in the early 1970's. It consists of two towers mounted on a pair of accurately aligned rails. The towers support all or parts of the source, receiver, and data systems as well as the rotators for supporting and positioning the antennas.

Both towers are free to move and the separation distance between them can be varied smoothly from 0 to 60 m. The towers are approximately 6 m high and the antennas under evaluation can be mounted 1 to 2 m higher if necessary. Means are provided for accurately aligning the antennas and for maintaining that alignment for all separation distances. The rails were originally aligned using a transit and precision level so that the maximum angular deviation of the antennas was less than ±0.02 degrees about any axis as the towers were moved the full length of the rails.

Applications:

NIST uses this facility primarily for the accurate characterization of antennas by measuring absolute gain and polarization parameters. For measurements above 1 GHz, the uncertainty in gain is approximately 0.1 dB for antennas with gains between 6 dB and 45 dB. The uncertainty in polarization axial ratio is about 0.05 dB/dB. Below 1 GHz, gain accuracies may degrade to about 0.25 dB for antennas with gains as low as 10 dB.

The facility is also useful for some far-field antenna measurements or for other types of measurements where it is important to know how a transmitted signal varies with distance—millimeter wave propagation studies, for example.

Availability:

Two kinds of arrangements can be made to use this facility. NIST staff can perform specified tests or measurements on a reimbursable basis. In this case, the customer has no direct use of the facility; all measurements are performed by NIST staff and the customer is issued a test report.

As an alternative, work may be performed on a cooperative basis with NIST staff, and the user is responsible in large part for the accuracy of test results. In either case, arrangements need to be made well in advance and reimbursement is required for the use of the facility and the time of NIST staff involved.

Contact:

Mr. Allen C. Newell, 4083 Radio Building, NIST, Boulder, CO 80303, 303/497-3743.

Ground Screen Antenna Range

The ground screen antenna range is an open area test site located at the National Institute of Standards and Technology.

Capabilities:

The ground screen consists of 1/4-in. mesh galvanized hardware cloth stretched over a level concrete slab. The screen is 30.5 m wide by 61 m long and is spring-loaded around the perimeter to ensure uniform tension, a flat surface, and adequate compensation for thermal expansion. The overall size of the ground screen permits far-field measurements in the HF portion of the spectrum while the mesh dimension provides for an efficient ground plane well into the UHF region.

Applications:

- Antenna calibrations;
- Antenna patterns at any polarization;
- Electromagnetic susceptibility measurements;
- Electromagnetic radiated emission measurements;
- Calibration of field intensity meters; and
- Wave propagation studies in frequency or time domains.

Availability:

This facility is used heavily in performing calibrations for industry and other government agencies. The facilities are available for independent or collaborative work with NIST.

Contact:

Dr. Motohisa Kanda, 4643 Radio Building, NIST, Boulder, CO 80303, 303/497-5320.

Transverse Electromagnetic (TEM) Cells

The National Institute of Standards and Technology has designed and constructed several transverse electromagnetic (TEM) cells that are available for use. A TEM cell is a device for performing radiated electromagnetic emission and susceptibility measurements of electronic equipment. It is designed based on the concept of an expanded transmission line operated in a TEM mode. The cell is a two-conductor system with the region between the inner and outer conductors used as the test zone. The tapered sections at both ends are required to match the cell to standard 50 Ω coaxial-cable connectors.

Capabilities:
The cell provides a shielded environment for testing without introducing multiple reflections experienced with the conventional shielded enclosure. It simulates very closely a planar far field in free space and has constant amplitude and linear phase characteristics. The external electromagnetic signals will not affect the measurement of low-level radiated emission from the device under test. The high-level test field generated inside a cell for radiated susceptibility tests will not interfere with external electronic systems.

Applications:
In addition to radiated electromagnetic compatibility/interference (EMC/EMI) testing, other applications of the TEM cells include the calibration of antennas and the study of biological effects of radiofrequency radiation.

Limitations:
The usable frequency range is limited by an upper bound determined by the appearance of the lowest high-order mode. The volume available for testing purposes is inversely proportional to this upper frequency limit. The size of the device to be placed inside a TEM cell for testing should be small relative to the available test volume in order that the field structure associated with the ideal TEM mode existing in an empty cell not be significantly perturbed.

Availability:
Several TEM cells with five different sizes and five upper frequency limits in the range 100 MHz to 1 GHz are available. In collaborative programs, NIST staff are available to advise and interpret measurement results. Independent testing also can be arranged.

Contact:
Dr. Motohisa Kanda, 4643 Radio Building, NIST, Boulder, CO 80303, 303/497-5320.

Transverse Electromagnetic Cell

Electromagnetic Anechoic Chamber

The electromagnetic (EM) anechoic chamber at the National Institute of Standards and Technology is a facility for generating standard (known) electromagnetic fields. Such fields are fundamental to the research, development, and evaluation of antennas, field probes, and EM material properties.

Capabilities:

EM fields up to 100 V/m can be established in the chamber over the broad frequency range from 200 MHz to 18 GHz, and up to 200 V/m for certain frequency bands above 1 GHz. A majority of the individual systems which compose the measurement system are under computer control, thus enhancing statistical control of the measurements. Work is under way to extend the frequency range to 40 GHz and to improve the computer control of the chamber systems. The chamber dimensions are 8.5 m, 6.7 m, and 4.9 m in length, width, and height, respectively.

Applications:

- Research, development, and evaluation of new EM field generation and measurement methods;
- Antenna and field probe development and evaluation;
- Calibration of field measurement instruments;
- Susceptibility testing of electronic equipment;
- Shielding effectiveness and material parameter studies; and
- Special tests for government agencies, industry, and universities.

Availability:

This facility is used heavily in performing calibrations for industry and other government agencies. The facilities are available for independent or collaborative work with NIST.

Contact:

Dr. Motohisa Kanda, 4643 Radio Building, NIST, Boulder, CO 80303, 303/497-5320.

High-Voltage Measurement Facility

The National Institute of Standards and Technology maintains a high-voltage measurement facility in which it develops and evaluates the measurement techniques needed in the orderly delivery of electric power for defense and to support industrial and university research. The major programs now being pursued using this facility are the measurement of transient voltages and currents; the development of techniques to quantify pre-breakdown and breakdown phenomena in liquid and gaseous dielectrics; and the measurement of low-frequency electric and magnetic fields.

Capabilities:

With existing power sources, direct voltages of 300 kV, 60-Hz alternating voltages of 175 kV, and standard lightning impulses of 500 kV can be produced. Selected waveforms, such as microsecond duration trapezoidal waveforms up to 300 kV and gated 60-Hz waveforms up to 100 kV, are also available. Supporting equipment includes high-voltage standard capacitors rated at 200 kV; high-accuracy, current-comparator bridges for 60-Hz measurements; a precision dc divider rated at 200 kV; dividers to measure standard lightning impulses up to 1-MV peak; partial discharge measurement systems; high-speed cameras and supporting optical equipment; a computer-controlled system to measure the electric field in transformer oil; a gas-chromatograph/mass-spectrometer system; a low-speed wind tunnel; and a system to produce a known electric field and current density in air at atmospheric pressure.

Measurement systems are available to measure pulsed voltages and currents with characteristic times ranging from nanoseconds to milliseconds. These systems include Rogowski coils and capacitive probes as well as the necessary recording equipment to acquire and store digital records. These conventional measurement systems are supplemented by optical sensors and couplers.

Applications:

Instrumentation and Component Evaluation. Impulse, ac, and dc dividers; electric and magnetic field meters; capacitors; transformers; lightning arresters; and ion counters.

Dielectrics Research and Development. Chemical degradation studies; measurement of the fundamental processes of discharge initiation; onset and magnitude of partial discharges; space charge measurement; streamer propagation studies.

Availability:

The high-voltage facility is used by NIST staff and by guest researchers from industry, universities, and other federal agencies. Use of the facilities must be scheduled in advance. Because of the complexity of the system, it is anticipated that typical use of the facility will be in the form of a collaborative investigation with staff from NIST.

Contact:

Dr. Robert E. Hebner, B344 Metrology Building, NIST, Gaithersburg, MD 20899, 301/975-2403.

High-Voltage Measurement Facility

Fire Research Facilities

As the federal government's principal fire research laboratory, the National Institute of Standards and Technology maintains some of the country's best and most extensive fire testing facilities. A substantial portion of NIST's fire tests are performed in a specially-equipped fire research building designed for large-scale fire experiments. The building is 27 m by 57 m. Smoke abatement equipment permits large fire tests to be conducted safely without polluting the environment.

In addition to several individual burn rooms, which are modified from time-to-time to accommodate special NIST testing requirements, the facility also houses several specially designed calorimeters for measuring the rate of heat release from materials and large samples, a new room/corridor facility for studying smoke and toxic gas transport, pilot furnaces, and reduced-scale model enclosures. Also, a two-story "townhouse" is used for studying fire spread from a burning room, smoke transport between levels, and sprinkler performance.

A new computer-based data acquisition system provides state-of-the-art data collection capabilities for all large-scale fire testing. Up to 300 instruments with scanning rates over 100 channels per second can be dedicated to a single test. During an experiment, real-time, full-color graphics present the data as they are collected, with automatic conversion to engineering units for gas analysis, rate of heat release, temperature, and other measurements.

A Fire Simulation Laboratory containing personal computers, state-of-the-art graphics, video and reference materials, and associated databases is used to develop, demonstrate, and apply fire modeling computer programs. The movement of smoke through a building is also simulated by injecting dyed salt water into a transparent model of the building in a large tank of fresh water.

Capabilities:

Heat-Release Rate Calorimeters. NIST pioneered and developed the oxygen consumption methodology for measuring the rate of heat release and has used it longer and in more devices than any other laboratory. The major benefit of this technique is the independence of the apparatus in measuring enthalpy responses to changes in heat release rate.

NIST has available two calorimeters for measuring the rate of heat release of free-standing items such pieces of furniture. The smaller one has a capacity of 1/2 MW and the larger, 7 MW. Provisions for measuring smoke production and gas species yield are available with both instruments.

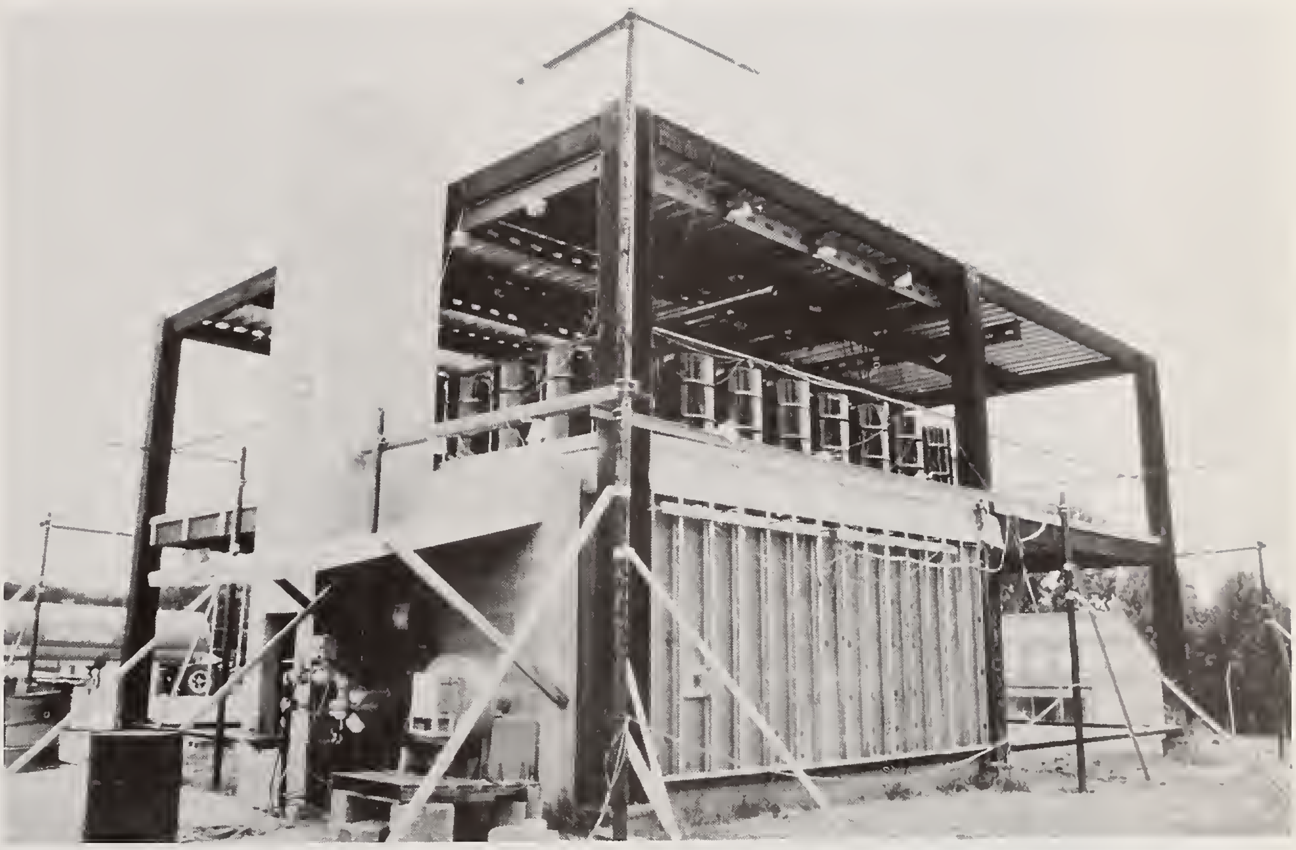
Room/Corridor Facility. NIST researchers have constructed and used a room/corridor facility to evaluate an analytical model that predicts the transport of smoke and toxic gases from the room of fire origin into the corridor and secondary target rooms. The design of this facility makes it possible to measure the hazards associated with the burning of wall linings or room furnishings by evaluating the rate of heat release, smoke production, and toxic gas generation. The facility is available in its present form or with design modifications for the evaluation of a variety of building contents and furnishings.

Burn Rooms. A standard burn room built to ASTM specifications, 2.4 m by 3.7 m by 2.4 m high, adjoins a large overhead hood which collects the exhaust products from the room fires. The exhaust collection system is calibrated to measure the rate of heat release and the generation rates of smoke and other combustion products from the fire. The burn room is available for developmental and validation studies of mathematical models and for studies of fire performance of furnishings and interior finish materials.

The room fire environment can be characterized in terms of temperature and pressure gradients and the spatial distribution of thermal flux, gaseous combustion products, and smoke. Other measurements permit the calculation of thermal losses to the room boundaries and mass and energy flows from the room. Other smaller burn rooms also are available.

Pilot Furnaces. Two pilot furnaces for evaluating the fire endurance of wall assemblies or floor/ceiling assemblies are available. These furnaces, one capable of handling specimens 2.4 m by 3.0 m and the other 1.0 m by 1.0 m, may be used for research purposes only and cannot be used for code acceptance testing. Typically, fire exposure similar to that specified by ASTM E 119, under carefully controlled conditions of furnace pressure and oxygen concentration, can be carried out. Depending on the parameters required, a variety of other exposure conditions can be applied.

Reduced-Scale Models. NIST facilities are available for reduced-scale modeling of full-scale fire configurations. Physical models offer an



Two-Story Structural Steel Facility Used in Fire Research economical means of achieving sufficient variation of physical parameters for a generalized understanding of fire behavior. Based on the results of reduced-scale experiments, limited full-scale verification then can be performed.

Two-Story Structural Steel Facility. This test structure consists of a two-story, four-bay structural steel frame measuring 9.75 m by 12.2 m. The steel frame is sized to reflect the structure typically found at mid-height of a 20-story building. A manually operated propane burner, with a capacity of 4.4 MW and requiring a 10 horsepower electric blower, is mounted in a masonry wall across one end of one of the bays.

Any of the eight compartments, or combinations thereof, can be enclosed to serve as a furnace or a burn compartment. The top of the structure has a poured concrete deck over steel, while the second story has a poured concrete deck over steel in two of the opposing quadrants. The other two quadrants have no floor. Extensive instrumentation and data acquisition capabilities are available for any part of the structure.

The test frame is available for use as a burn compartment in which products could be burned and the resulting energy and combustion product measured. The bay containing the burner wall can be used as a fire endurance furnace for evaluating walls or floor/ceiling assemblies.

Fire Simulation Laboratory. The laboratory contains four personal computer workstations, two high-resolution graphics workstations, a digitizing table for entering building design data, a plotter, and a printer. The workstations are connected to NIST's mainframe computers, a minicomputer, and the computerized database in the Fire Research Information Service.

Computer programs available for use and development in the laboratory address room fire growth, fire and smoke transport through buildings, building structural fire protection, escape and rescue, and sprinkler response. Special graphic display programs are also available. A database for use with some of the programs has been assembled.

Availability:

Industry, university, and government representatives are encouraged to use NIST fire testing facilities on a collaborative or independent basis, with certain restrictions. For safety reasons, NIST staff must closely supervise all use of such facilities.

Contact:

Dr. Jack E. Snell, A247 Polymer Building, NIST, Gaithersburg, MD 20899, 301/975-6850.

Large-Scale Structures Testing Facility

The large-scale structures testing facility at the National Institute of Standards and Technology consists of a universal testing machine (UTM) that may be used with a 13.7-m-high reaction buttress equipped with a horizontal hydraulic ram of 4.5 MN capacity. A combination of horizontal and vertical forces may be applied to large-scale specimens.

Capabilities:

The universal testing machine portion of the facility is a hydraulically operated machine of 53.4 MN capacity and is one of the largest in the world. It tests large structural components and applies the forces needed to calibrate very large capacity force measuring devices. It can apply compression forces to column sections or fabricated members up to 17.7 m in height. The reaction buttress will resist horizontal forces to 4.5 MN from floor level to 12.2 m high. Flexure and tension specimens may be subjected for forces up to 18 MN and 26 MN, respectively. Two-meter-thick test floors east and west of the machine may be utilized to tie specimens in place.

A servo system has been added to the original manual controls of the UTM. It may be programmed by function generator or computer to create any desired loading function using force, strain, or displacement as the variable.

Loads may be applied to a specimen by both the UTM and horizontal ram. A four-rail track system equipped with low-friction rollers has been used for concrete column tests. An "A" frame was used to resist horizontal reaction forces generated by the ram and was attached to the buttress at the desired height.

Applications:

Recently a testing program was conducted to evaluate the performance of concrete columns 1.5 m in diameter and up to 9.1 m high. Another test series is evaluating fracture propagation in steel plates 1 m wide and 0.1 m and 0.15 m thick. A third experiment used the servo-control system programming repeated loads applied to composite specimens.

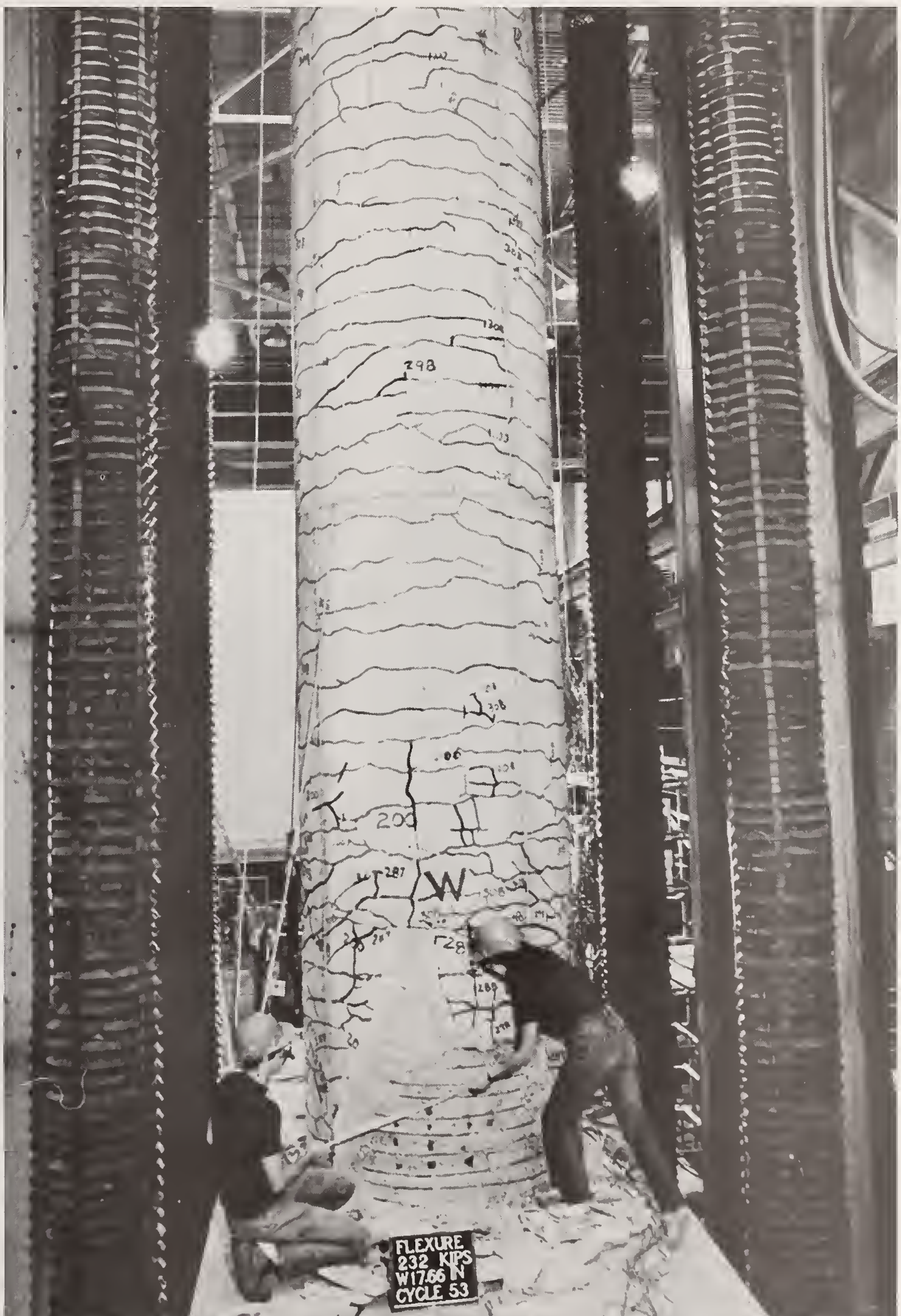
Low-cycle fatigue tests, destructive or ultimate loads, earthquake simulation in two dimensions, and complex loading of components may all be accomplished in this facility. Servo-operation of this machine creates a unique potential for precisely controlled very large forces applied to test components.

Availability:

Collaborative or independent programs for this test facility are arranged through NIST. The facility must be operated by NIST staff. Tests should be arranged as far in advance as possible. Special hardware may be necessary for specimen attachment.

Contact:

Dr. Charles G. Culver, B268 Building Research Building, NIST, Gaithersburg, MD 20899, 301/975-6048.

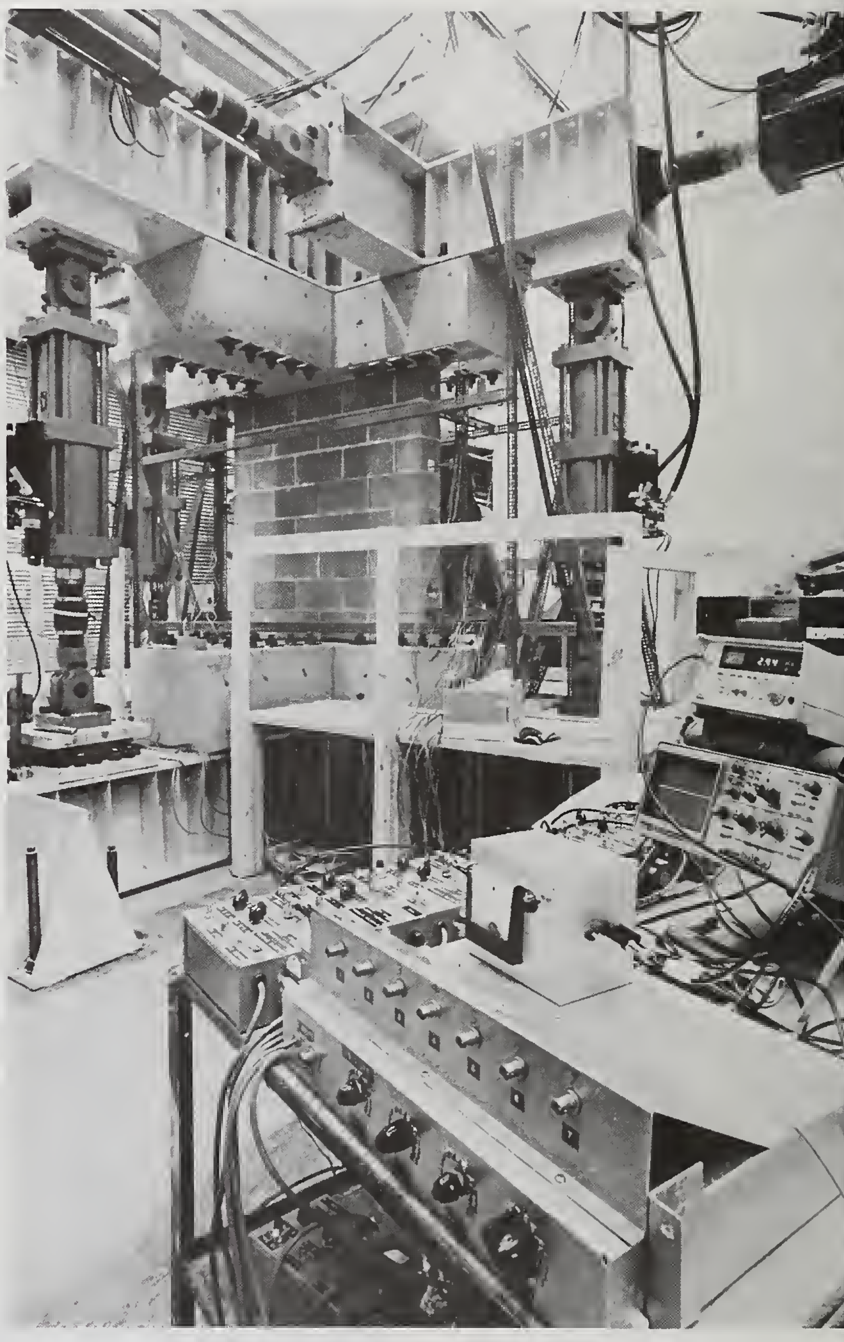


Universal Testing Machine in the Large-Scale Structures Testing Facility

Tri-Directional Test Facility

The tri-directional test facility at the National Institute of Standards and Technology is a computer-controlled apparatus capable of applying cyclic loads simultaneously in three directions. It is used in examining the strength of structural components or assemblages under the application of a variety of loading phenomena such as earthquake or wind. This is one of the largest such facilities in the world, both in terms of its high load capacity and its capability to handle large, full-scale specimens.

Capabilities:
The facility can apply forces and/or displacements in 6 directions at one end of a specimen. The other end of a specimen is fixed. Specimens up to 3.3 m high and 3 m in length or width may be tested. The 6 degrees of freedom are translations and rotations in and about three orthogonal axes. The forces are applied by six closed-loop, servo-controlled hydraulic actuators that receive instructions from a computer. Operating under computer control, the facility simultaneously maintains control of the load and/or dis-



Tri-Directional Test Facility

placements in each of the three orthogonal directions. Loads may be applied up to 2000 kN in the vertical and about 890 kN in each of the two horizontal directions.

Applications:
The tri-directional test facility is limited only by the size of the test specimen. Loads may be cyclic or unidirectional depending on the type of loading condition being simulated. Currently the facility is being used to study masonry shear walls subjected to reverse cyclic lateral loading and precast concrete connections also subjected to reversed cyclic lateral loading. This facility supports NIST's role in conducting research for seismic design and construction standards in the National Earthquake Hazards Reduction Program.

Availability:
The tri-directional test facility is used by NIST staff in a variety of NIST research projects and collaborative projects with other agencies. It also is available for independent research, but must be operated by NIST staff.

Contact:
Dr. Charles G. Culver, B268 Building Research Building, NIST, Gaithersburg, MD 20899, 301/975-6048.

Calibrated Hot Box Facility

This National Institute of Standards and Technology apparatus measures the heat transfer coefficient of full-scale building wall sections. Designed in accordance with ASTM standard C-976, it consists of two large heavily insulated chambers—an environmental chamber and a climatic chamber—each with one open side. Indoor and outdoor conditions are simulated in the chambers. The open test section measures 3 m by 4.6 m. A well-insulated frame supports the wall specimen that is clamped between the open sides of the two chambers.

Capabilities:
This facility is the only one of its kind designed to perform simultaneous dynamic transfer measurements of air, moisture, and heat during simulated winter and summer conditions under steady state and dynamic climatic conditions. While the environmental chamber temperature and humidity are maintained to simulate a relatively steady and narrow range of indoor conditions, the climatic chamber can attain temperatures ranging from –40 to 65 °C. The apparatus measures the performance of homogeneous or composite walls having a range of thermal resistance from 0.35 to 8.8 $m^2 \cdot C/W$. It accommodates wall specimens up to 0.6 m thick and up to 700 kg/m^2 in weight per unit area.

Applications:
NIST researchers use the facility to develop standard test

Calibrated Hot Box Facility

methods to evaluate dynamic thermal performance of full-scale walls under cyclic temperature conditions. These test methods do not currently exist. The building industry and government agencies are seeking reliable evaluation techniques for wall thermal mass, especially to predict energy consumption of buildings with heavy mass effects in comparison to standard wood-frame buildings.

NIST has participated in round-robin test activities with domestic and overseas thermal insulation laboratories.

Availability:

The facility provides a unique opportunity to measure simultaneous transfer of air, moisture, and heat through wall and roof specimens with openings for windows and doors. While it is available for use by those outside NIST, this apparatus must be operated by NIST staff.

Contact:

Dr. A. Hunter Fanney, B322 Building Research Building, NIST, Gaithersburg, MD 20899, 301/975-5864.

Line Heat-Source Guarded Hot Plate

This 1000-mm guarded hot-plate apparatus at the National Institute of Standards and Technology measures the thermal conductivity of building insulation. NIST researchers use the hot plate to provide calibration specimens for guarded hot plates in other laboratories. It also is used to investigate edge heat loss from thick thermal insulation materials. This facility is the only one of its kind in the world which will permit low-density thick insulation to be measured with an uncertainty of less than 0.5 percent.

Capabilities:

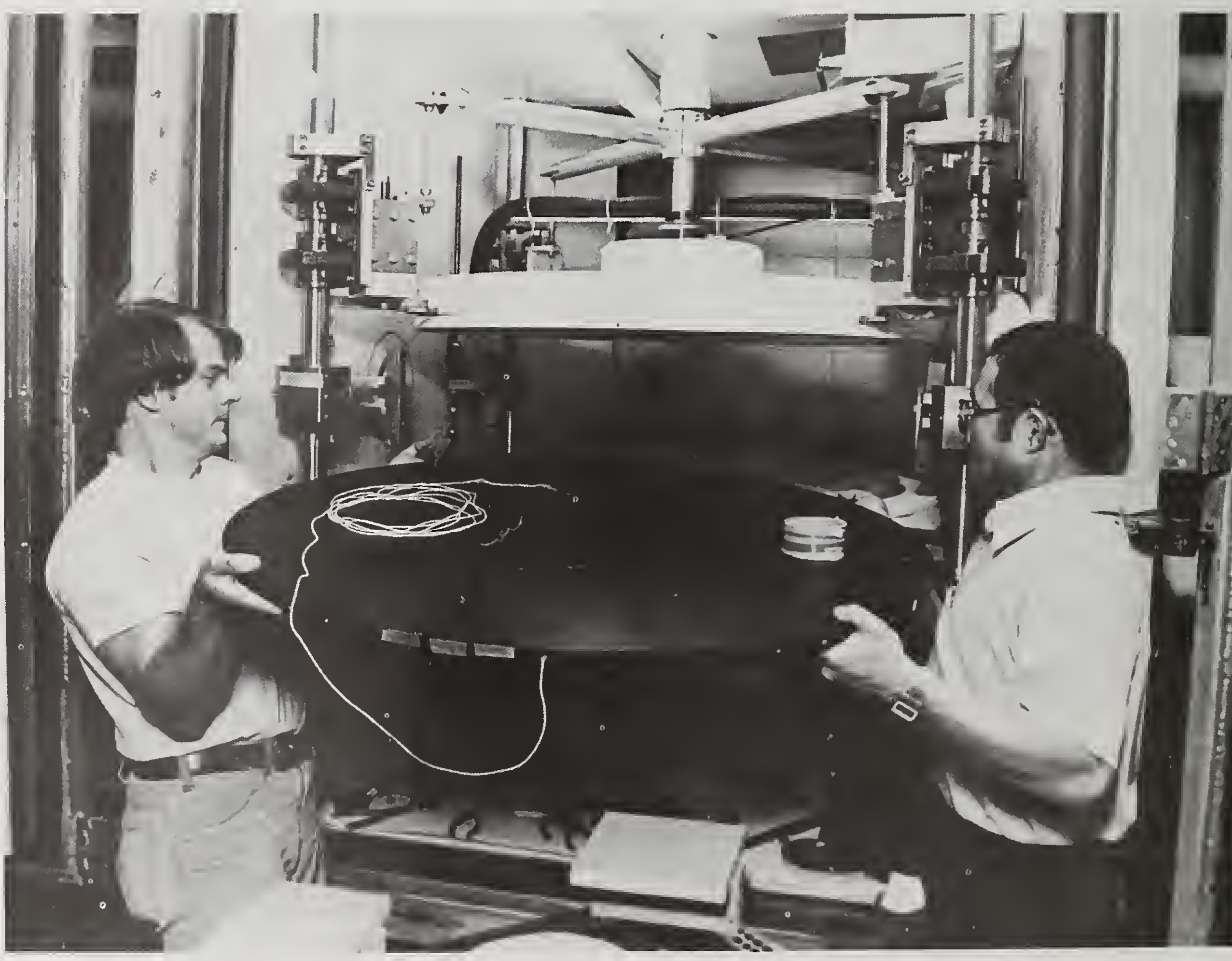
This apparatus has a test temperature range of 80 °C for the hot plates and −20 °C for the cold plates. The apparatus permits measurement of vertical and horizontal heat flow to simulate the heat transfer through ceilings and walls, respectively. This apparatus operates within its own carefully controlled temperature and humidity environment shielded by an insulated aluminum enclosure. This facility provides for absolute measurement of thermal resistance of thick and low-density test specimens used as transfer standards. These standards are used to calibrate or verify heat flow meter (ASTM C508) or guarded hot-plate (ASTM C177) equipment.

Availability:

This apparatus is available for use by those outside NIST, but it must be operated by NIST staff. Collaborative programs may be arranged.

Contact:

Dr. A. Hunter Fanney, B322 Building Research Building, NIST, Gaithersburg, MD 20899, 301/975-5864.



Line Heat-Source Guarded Hot Plate

Large Environmental Chamber

The large environmental chamber at the National Institute of Standards and Technology is 14.9 m by 12.8 m by 9.5 m high. It has an earth floor and may be excavated as needed for building construction. The chamber is one of the largest of its kind, capable of accommodating two-story houses under simulated environmental conditions. This chamber has been used for thermal performance, heating and cooling load measurements, and energy consumption of buildings of different kinds.

Capabilities:

The chamber is capable of automatically maintaining steady and/or dynamic temperature profiles from −45 to 65 °C and humidity from 50 percent RH at 1.7 °C up to 35 °C dewpoint at 49 °C. A wider range of relative humidity (15 to 80 percent) may be obtained manually. Air circulation maintains the temperature variation within the chamber to within ±1 °C. Damper-control return ducts in all four corners of the chamber permit good air distribution. Supply air is furnished by ceiling diffusers.

Applications:

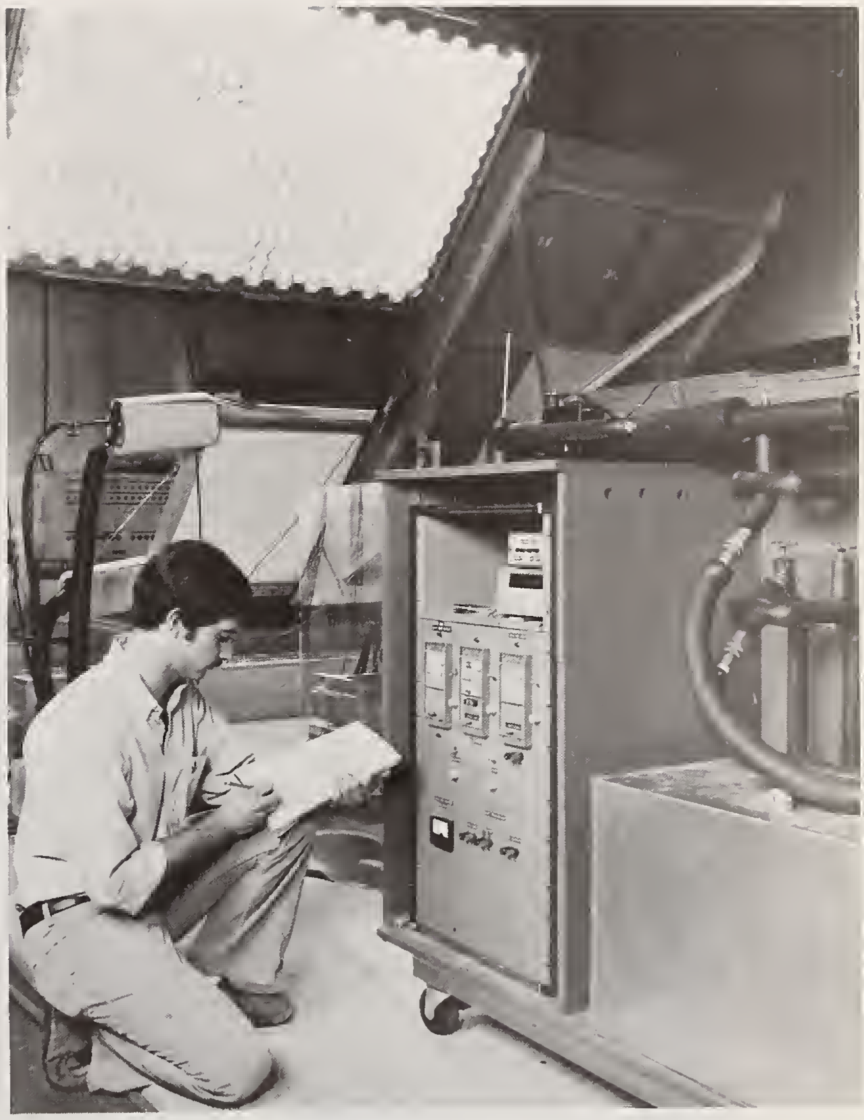
The chamber is used to measure indoor temperature fluctuation, heat loss and heat gain through building envelopes, energy conservation and moisture condensation studies, and air infiltration under simulated and dynamically fluctuating outdoor temperature cycles. The chamber has been used to test a wide variety of conventional and special structures and equipment, including military hardware (such as inflatable life rafts, relocatable air-inflatable hospital units, and portable walk-in coolers) under extreme climatic conditions.

Availability:

This facility, along with several smaller chambers (including one designed for vehicles), has substantial potential for use by researchers in industry and universities. Collaborative programs and individual research can be arranged.

Contact:

Dr. David Didion, B114 Building Research Building, NIST, Gaithersburg, MD 20899, 301/975-5881.



Large Environmental Chamber

Acoustic Anechoic Chamber

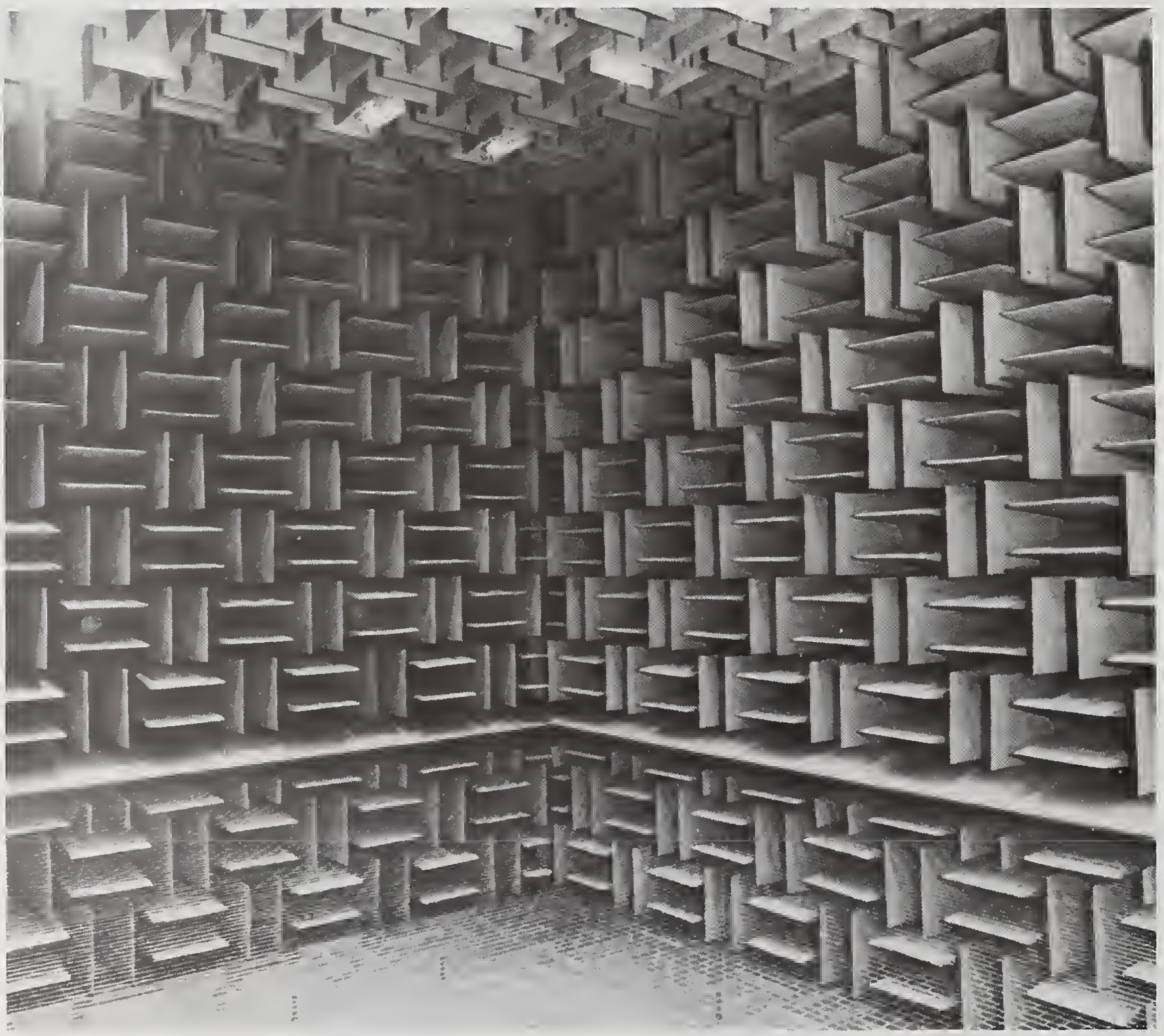
This NIST facility is used to determine the sound power emitted by sound sources as well as how much sound power flows in a given direction. It also is used to calibrate acoustical equipment such as microphones and loudspeakers. The facility is a vibration-isolated, shell-within-shell structure 6.7 m by 10.0 m by 6.7 m, creating a volume of 450 m^3. The absorptive treatment consists of glass wool wedge modules installed on all six inner surfaces of the room. Access to equipment within the room is provided by a wire mesh floor. Additional accessories in the room include communication line outlets and rigid supports for equipment on all six surfaces. Air-conditioning ducts are acoustically treated. Humidity control provides 45 percent relative humidity within ±5 percent.

Capabilities:
The chamber is designed to provide a highly anechoic sound field. The walls of the chamber are designed to absorb 99 percent or more of the normally-incident sound energy at all frequencies above 45 Hz. The chamber's airflow can be cut off if a lower background sound level is required.

Applications:
The chamber is used to develop procedures for measuring sound power, to determine the direction of sound intensity, and to calibrate acoustical instruments. It supports basic research to define the acoustical parameters required for the development of mathematical models for predicting acoustical fields.

Availability:
This facility has substantial potential for use by researchers in industry, universities, and other government agencies. Scheduling arrangements for collaborative programs and individual research are handled by NIST.

Contact:
Mr. Daniel R. Flynn, B147 Sound Building, NIST, Gaithersburg, MD 20899, 301/975-6634.



Acoustic Anechoic Chamber

Nitrogen Flow Measurement Facility

The nitrogen flow measurement facility at the National Institute of Standards and Technology is a mass-based reference system capable of both liquid and gas flow measurement. It is well instrumented for temperature and pressure, and it is an adaptable facility, capable of a variety of piping arrangements. Located completely indoors, it is not subject to environmental changes.

Capabilities:

When configured for gas flow measurements, the facility has a flow rate range of 0.5 to 2.4 kg/s. In this mode, the nitrogen gas is at pressures of approximately 4 MPa and temperatures of approximately 288 K. The facility has a flow rate range of 0.05 to 10 kg/s when set up for liquid flow measurements. The liquid nitrogen can be at pressures up to 0.7 MPa and temperatures between 75 and 90 K in this configuration. A continuous flow facility, it permits dynamic mass flow measurements. For volume flow measurements, density is determined by making pressure and temperature measurements and calculating density from an equation of state.

Applications:

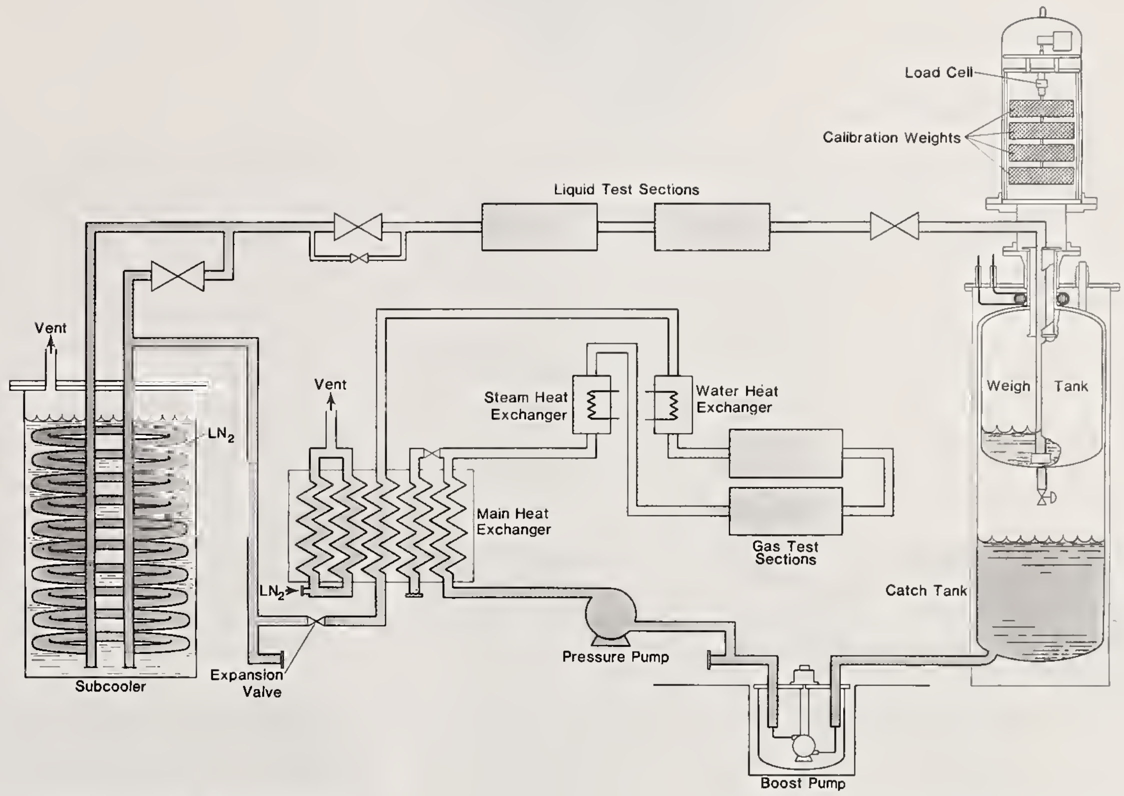
The nitrogen flow facility can be used for testing a variety of flow measurement instrumentation including flowmeters, temperature sensors, pressure sensors, and densimeters. The ability to operate the facility at stable conditions for long periods of time permits testing of instrumentation stability. The ability to vary system parameters permits testing of instrument sensitivity.

Availability:

Collaborative or independent programs for this test facility can be arranged. The facility must be operated by NIST staff.

Contact:

Mr. James A. Brennan, 1003 Cryogenics Building, NIST, Boulder, CO 80303, 303/497-3611.



Nitrogen Flow Measurement Facility

Water Flow Measurement Facility

The NIST water flow measurement facilities comprise the national standards for flowrate. These facilities are used to establish, maintain, and disseminate flowrate measurements, standards, and data for the widely ranging flow conditions needed by U.S. industry. Industry requests for these facilities include numerous flow meter calibrations, round robin testing programs to establish realistic traceability chains in the form of flow measurement assurance programs, data generation programs for industrial groups and trade associations, and test beds for carrying out industrial research programs focused on flow measurement topics.

Capabilities:

Water flow facilities enable flowrates up to 40,000 liters/min in pipe sizes that range up to 500 mm in diameter. Maximum operating pressure is 1 MPa. Flowrate determination schemes use static and dynamic gravimetric systems.

Application:

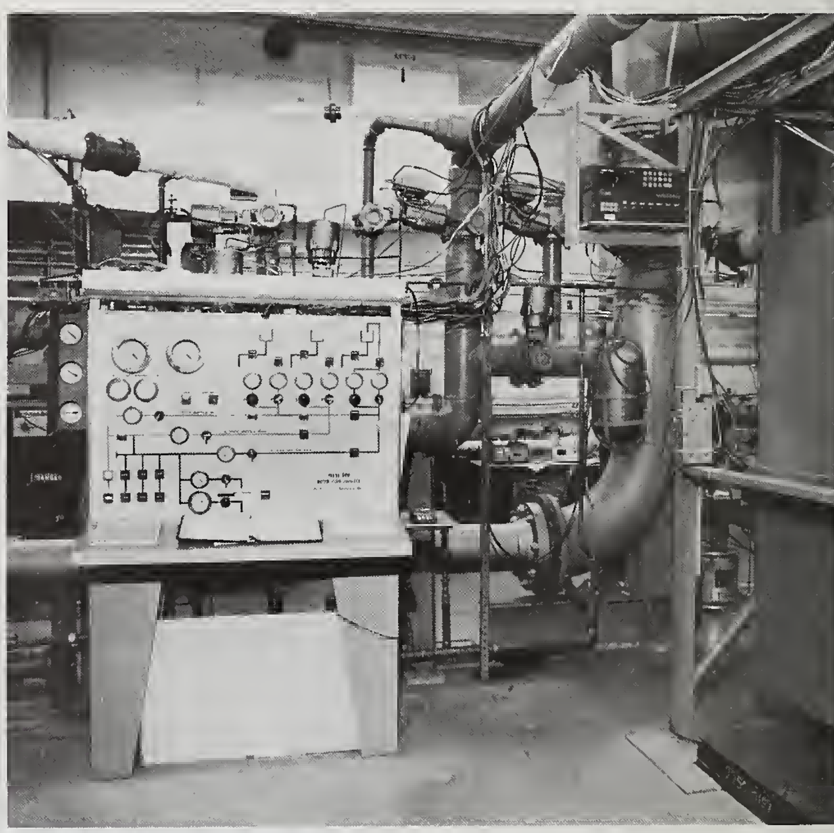
These facilities are applied to the tasks of establishing and maintaining the national bases for the liquid flowrate measurement systems. The end result is orderliness in the marketplace, both domestically and internationally, for U.S. industries involved in the custody transfer and/or process control of valuable fluid resources and products. Applications include those of the National Aeronautics and Space Administration, the Department of Defense, the oil and gas industries, the chemical and related industries, the power and energy-generation industries, etc.

Availability:

These facilities are available upon request to U.S. industry, other government agencies, and academia. Their use can be shared with the requestor, i.e., calibrations and related research projects can be done collaboratively.

Contact:

Dr. George E. Mattingly, 105 Fluid Mechanics Building, NIST, Gaithersburg, MD 20899, 301/975-5939.



Water Flow Measurement Facility

Information Systems Engineering Facility

The information systems engineering facility at the National Institute of Standards and Technology provides computer hardware and software to support the research and development of standards, guidance to federal agencies, and validation tests. The following areas are included: graphics; programming languages; database management systems; distributed database management systems; data dictionary systems; data administration, especially database design; data interchange; knowledge-based and expert systems; and Geographic Information Systems (GIS).

Capabilities:

The facility contains a variety of computers, including VAX 11/785, Symbolics 3650 and 3600 LISP machines, COMPAQ 386 and Macintosh II workstations, microcomputers, Silicon Graphics IRIS workstation, and Chromatics 7900 graphics terminal. Various other computer systems are accessible, including the NIST CDC 205 supercomputer. The facility contains a variety of hard-copy output devices, such as laser printers, camera output systems, and a color ink jet plotter.

Software used in the facility includes:

- Graphical Kernel System (GKS) and Programmer's Hierarchical Interactive Graphics System (PHIGS) implementations which allow graphics programmers to design a wide variety of graphics programs, ranging from simple passive graphics to complex real-time systems;
- Computer Graphics Metafile (CGM) implementations which allow transfer of graphical pictures among heterogeneous graphic devices;
- a variety of programming language processors and system software;
- database management systems for the VAX and microcomputers;
- a prototype implementation of the Information Resource Dictionary System (IRDS) draft proposed standard;
- LISP and Prolog; and
- microcomputer expert system shells.

Validation suites are available for testing conformance to the Federal Information Processing Standards (FIPS) for COBOL, FORTRAN, BASIC, Pascal, Ada, GKS, and database language SQL. Testing services are provided for COBOL, FORTRAN, Ada, and GKS.

Applications:

An active area of cooperative work is the development and evaluation of tests to validate the conformance of language processors and other system software to FIPS. The major programs now being pursued include validation of the programming language processors COBOL, FORTRAN, and Ada; validation of the GKS, PHIGS, and CGM graphics systems; and continued work on SQL.

Possible future work includes the development of tests and procedures for validating additional programming language systems including VHSIC Hardware Description Language (VHDL), MUMPS, C, LISP, and Prolog; for validating the Com-

Information Systems Engineering Facility puter Graphics Interface (CGI); and for validating the following data management and data interchange software: IRDS, Data Description File for Information Interchange (DDF), and Abstract Syntax Notation One (ANS.1).

Other areas appropriate to cooperative work include the development of software standards and guidance for GIS and for the application of knowledge-based and expert systems to the design and operation of complex, distributed information systems.

Availability:

The facility is available for collaborative projects in test development. It must be used under the cognizance of NIST staff.

Contact:

Dr. David K. Jefferson, A266 Technology Building, NIST, Gaithersburg, MD 20899, 301/975-3262.

Computer and Network Security Facility

The NIST computer and network security facility is used to develop and evaluate methods for improving the security of computer systems and distributed computing networks. The facility is equipped with mini- and microcomputers, security devices, terminals, personal identification systems, and access to large mainframes and supercomputers through local-area, national, and global networks. A variety of communications technologies and applications environments are available for research efforts, including OSINET, a global research network for developing and testing Open Systems Interconnection (OSI) standards.

Capabilities:

The facility currently supports research in the application of methods to protect the secrecy and integrity of information in computer systems and data networks; the evaluation of personal identification and authentication techniques to control access to information resources; and the development of computer and network security architectures to determine where controls for integrity and confidentiality of information and authentication of users should be implemented.

Applications:

The facility is used primarily to develop and test federal, national, and international standards for computer and network security. Support is provided to the Department of Treasury and to the NIST Workshop for Implementors of Open Systems Interconnection (OSI), a joint government/industry activity that is advancing the implementation of international OSI standards in commercial network products.

Availability:

Collaborative research programs can be arranged.

Contact:

Mr. Stuart Katzke, A216 Technology Building, NIST, Gaithersburg, MD 20899, 301/975-2929.

Computer and Network Security Facility

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