
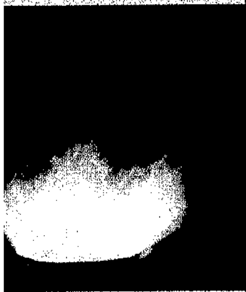
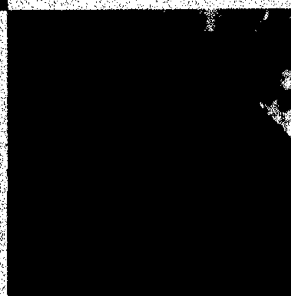

1998

Building & Fire Research Laboratory

Activities, Accomplishments & Recognitions

NIST

U.S. Department of Commerce

Technology Administration

National Institute of Standards and Technology

Contents

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What BFRL Is and Does

- 200 worldclass staff
- accomplishments show impact
- unique facilities
- $28 million annual budget
- over 90 years experience; sharply focused program
- access to advanced technologies
  - mathematical modeling
  - high-speed instrumentation
  - non-destructive testing and diagnostics
  - information technologies

Getting the Most from What BFRL Does

- laboratory visits to share information
- cooperative research and problem solving, access to unique resources
- cooperative proprietary research to achieve customer's technology mission, with industry partner holding rights to intellectual property
- guest researcher assignments for collaborative research
- research consortia to solve industry-wide problems
- invention licensing

BFRL Vision

Leader in performance prediction and measurement technologies; focal point for advances in key areas of technology; and partner with customers to exploit the benefits of these technologies.

BFRL Goal

Meet the critical measurement and standards infrastructure needs of the construction and fire safety communities.

BFRL Mission

Partner with its customers to provide the measurement technologies, performance prediction methods, and technical advances needed to enhance the competitiveness of U.S. industry, public safety and environmental safety, and assure the life cycle quality and economy of constructed facilities.

Building & Fire Research Laboratory

1998 Activities, Accomplishments, and Recognitions

We of the Building and Fire Research Laboratory (BFRL) are pleased to present to our clients and collaborators, this report of our 1998 impacts, accomplishments, recognitions, and activities. As one of the National Institute of Standards and Technology's measurements and standards laboratories, we provide performance prediction methods, measurement technologies, and technical advances needed to assure the life cycle quality and economy of constructed facilities — residences, commercial and institutional buildings, industrial facilities, public works, and utilities. We are enthusiastic about our work, conducted in close collaborations with industry, government, and academia, because of its importance to the productivity and competitiveness of all U.S. industry and everyone's quality of life.

In 1998, we focused on 10 objectives using multidisciplinary teams to achieve the greatest practicable impacts of our work. This report describes the purpose, approach, and principal 1998 impacts and accomplishments for each objective. In addition, we have continued substantial investments in longer term and fundamental research to be prepared for the challenges and opportunities of the future. Research highlights are found in the next chapter.

BFRL addresses the measurement and standards needed to achieve the National Construction Goals developed with industry by the Subcommittee on Construction and Building (C&B) of the President's National Science and Technology Council. C&B's activities are summarized in this report because of the substantial investment of BFRL in leadership of C&B and because of its influence on our program. C&B's major accomplishment in 1998 was the President's announcement, with industry, of the Partnership for Advancing Technology in Housing (PATH). PATH brings together government and industry to develop, demonstrate, and deploy housing technologies, designs, and practices to create homes that are stronger, more affordable, more comfortable, and far more energy efficient. In addition to the programs of the individual federal agencies, C&B is working with industry to develop a Partnership for Advancing Infrastructure and its Renewal (PAIR), and to Streamline the Building Regulatory System to reduce substantially the time and cost for achieving regulatory approvals.

We look forward to your inquiries and to our continued and strengthened collaborations.

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BFRL's research is focused and linked with collaborative private- and public-sector activities to help achieve the National Construction Goals (NCGs) developed with industry by the National Science and Technology Council's Subcommittee on Construction and Building (C&B). In 1996, groups of industry leaders representing the residential, industrial, public works, and commercial/institutional sectors developed industry strategic plans for achieving the NCGs in cooperation with federal agencies. These industry plans and direct discussions with industry leaders helped shape the direction of BFRL research.

BFRL's 10 Objectives

BFRL's 1998 research program is sharply defined under 10 key objectives:

- Computer-Integrated Construction Environment
- Cybernetic Building Systems
- Fire Safe Materials
- Industrial Fire Simulation
- Partnership for High Performance Concrete Technology
- Performance Standards System for Housing
- Service Life of Building Materials
- Metrology for Sustainable Development
- Earthquake, Fire, and Wind Engineering
- Advanced Fire Measurements and Fire Fighting Technologies

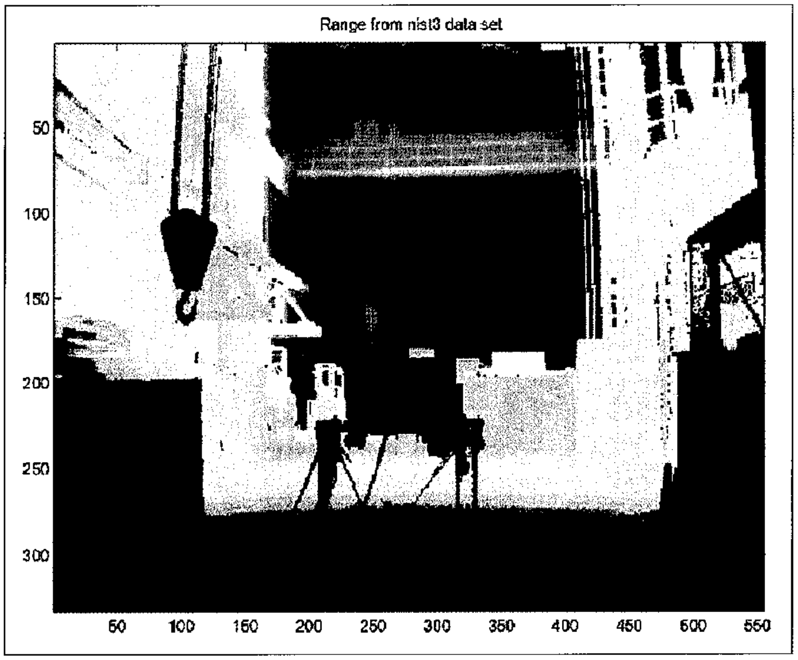
The 10 objectives comprise six major products plus four focused project areas that address the NCGs and industry plans. About 50 percent of BFRL's direct appropriations fund the first six BFRL objectives. Each is focused on a product that will bring prompt economic benefits. Objectives 7 through 10 are focused areas funded by direct appropriations and by other federal agencies. This research is smaller in scale and includes projects aimed at high economic impact and others focused on fundamental research for the next generation of technologies.

BFRL provides measurement technologies and performance prediction methods as illustrated in the two pictures. On the left, Mr. Thomas Cleary, chemical engineer, is operating BFRL's recently developed fire emulator/detector evaluator apparatus to evaluate a smoke detector's output signal and alarm function. On the right, Dr. Mark A. Kedzierski, mechanical engineer, is performing measurements of bubble growth for use in developing computer models that will help industry design evaporators for alternative refrigerants.

I

Computer-Integrated Construction Environment

INTENDED OUTCOME. *Developed and demonstrated, in partnership with U.S. industry, the effective electronic automation and integration of life-cycle work processes in the office and on the job site. Particular emphasis is placed on capital projects in the process plant industries, accounting for $40B in new construction each year, with the expectation of reducing delivery time and life-cycle costs and increasing quality and performance. The BFRL product will be a harmonized set of proven information technology standards leading to commercial implementations in software systems; a NIST testbed demonstrating the interoperability of the commercial systems; assistance to industry in re-engineering its work processes employing these standards and systems; prototype metrology and automation systems that advance the state of the art in construction; and supporting economic studies. BFRL is actively partnering with companies such as Merck, industry consortia such as PlantSTEP, Inc., and the International Alliance for Interoperability, and universities such as Carnegie Mellon University and Stanford University. This product will be delivered in stages, commencing in 1999 with the release of the ISO/STEP application protocol on plant spatial configuration and the initiation of a concomitant industry pilot project, and concluding in 2003 with industry take-up of the prototype metrology and automation systems.*



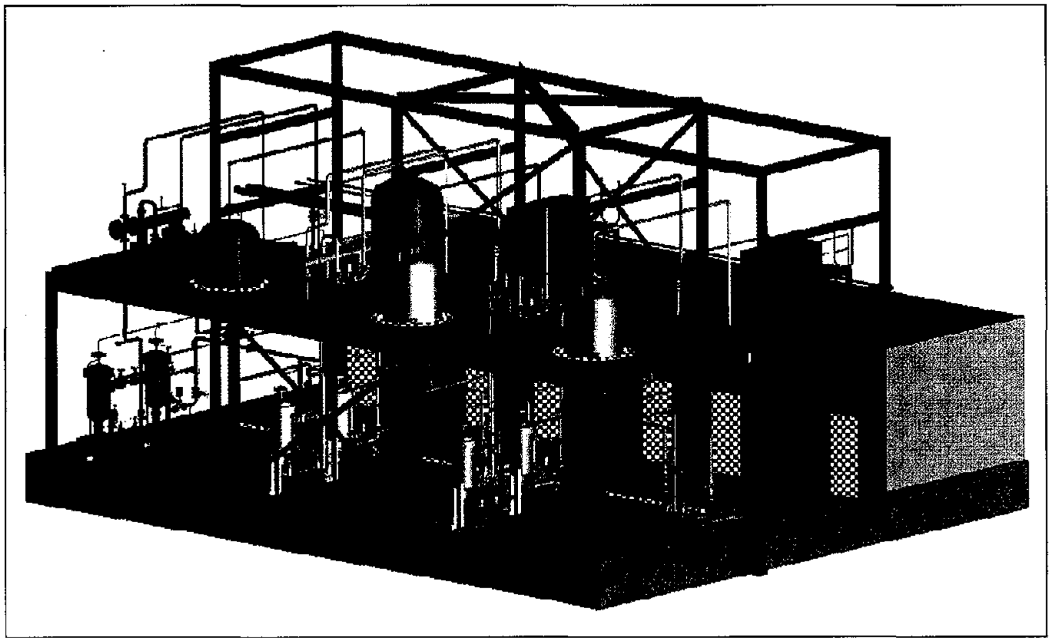
Light Detection And Ranging (LIDAR) range map of the inside of the National Construction Automation Testbed Laboratory, showing NIST's robot crane TETRA that was linked and automated with BFRL's 30-ton overhead bridge crane. The new scanning technology enables the automated creation of a 3D "as-built" digital model of the laboratory that can be used for construction planning and robotic programming.

Construction Metrology and Automation

The emergence of high-speed computer communication networks (the information superhighway) and the rapid advance of real-time, immersive, computer graphics (virtual reality) technologies presage the ability to manage remote construction sites from central offices and to automate certain portions of the tasks performed on-site. Limited demonstrations of this type of technology, largely relating to the control of robotic spacecraft and, more pertinently, to the tele-operation of simple machines for the handling of nuclear waste, have been conducted. The widespread use of this technology by the construction industry, however, is effectively prevented by several barriers including the cost of the new technologies, the lack of off-the-shelf integrated systems, and a lack of compelling full-scale demonstrations.

Dr. William Stone, leader, and the staff of the Construction Metrology and Automation Group are developing wireless real-time metrology systems, integrating these systems with construction machines and field-portable quality control equipment, and developing the means to operate on data obtained from the field. This will make it possible for contractors to obtain timely information about their job site that would never before have been possible. In the process, BFRL is developing recommendations for industry-consensus standards for the communication storage and dynamic access of live metrology data from the construction site.

NIST completed a portion of this new technology by establishing the National Construction Automation Testbed (NCAT). In one demonstration, a full-scale 30-ton bridge crane on NIST's Gaithersburg campus was converted to robotic control. The data from the crane were wire-



This 3-D model of a process plant serves as a basis for BFRL test files for implementation of the new ISO Standard, STEP AP 227.

lessly relayed to a high-speed network and run to a remote site in Washington, D.C. where Congressional members and staff were able to remotely operate the crane. They also witnessed the events in real-time by means of a 3D site simulator, which converted the data to a graphical representation of the crane's position.

These technologies will be expanded in FY 1999 in the areas of non-intrusive scanning technologies (for initial assessment of earthmoving progress) and discrete component tracking technologies (for instantaneous "as-built" site model generation). Both of these will be demonstrated to contractors at full scale in the coming year.

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International Standards for Exchanging Plant Engineering Information

Mr. Mark Palmer, research mechanical engineer, has been working with industry to deliver effective data exchange standards to advance the international competitiveness of U.S. engineering, construction, process and power, and CAD/CAE industries. In the international world of process plant design, construction, and operation, the rapid and accurate exchange of technical information among owners, designers, equipment suppliers, fabricators, and others is critical. Incompatible data exchange formats can lock corporations out of profitable national and international process plant projects.

Working with PlantSTEP, Inc. and leaders from the process plant industries, Mr. Palmer and colleagues completed the draft International Organization for Standardization (ISO) Standard, ISO 10303-227: Plant Spatial Configuration. This standard, commonly referred to as STEP Application Protocol 227, will enable the automatic exchange of plant engineering information, including 3-D models of plants and the detailed engineering of piping systems. AP 227, Plant Spatial Configuration, was approved unanimously by ISO as a Draft International Standard in May 1998. Commercial implementations of AP 227 are expected in the beginning of 1999.

Additionally, Mr. Palmer and colleagues worked with pdXi (Process Data eXchange Institute of AIChE) to develop the Committee Draft (CD) of STEP AP 231 for exchanging process design information and process specifications for major equipment. The AP 231 document was submitted to ISO for review and ballot in September 1998. The combination of these two application protocols enables broader collaboration across process, engineering and manufacturing companies and across the life cycle of process plants. This will lead to more cost-effective and safer process plants, while advancing the capabilities of U.S. engineering and construction companies to compete globally. These standards are important components for the wide application of information exchange across the life cycle of constructed facilities in general.

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II

Cybernetic Building Systems

INTENDED OUTCOME. *Developed, tested, integrated, and demonstrated open Cybernetic Building System — performed in cooperation with industrial partners, building owners and operators, and newly developing service companies — for improved productivity, life cycle cost savings, energy conservation, improved fire safety, improved occupant satisfaction, and market leadership. The BFRL product will be a full scale demonstration of a Cybernetic Building System delivered in a government owned office building complex in 2002.*

Mr. Steven Bushby, electronics engineer, checks wiring connections for controllers in the BACnet™ Virtual Building.

BACnet™ Expansion

BACnet™ is a standard communications protocol for building automation and control systems developed by BFRL with a number of industry partners under the auspices of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). BACnet™ provides a standard communications infrastructure through which building automation and control devices made by different manufacturers can be interconnected. This makes it possible for building owners, including government agencies, to obtain competitive upgrades to building control systems. In addition, BACnet™ makes possible the integration of building systems that currently stand alone. In June 1995, BACnet™ was approved as an ASHRAE standard and, later, as an American national standard by the American National Standards Institute (ANSI). It has been selected as a European Community pre-standard by the European Committee for Standardization. Today, there are over 4,000 installed systems running BACnet™ in at least 14 countries.

In 1996, the largest federal building west of the Mississippi River (132,000 m^2), in San Francisco, was selected by the General Services Administration (GSA) for the first large-scale demonstration of BACnet™ among multiple vendors. Mr. Steven Bushby, electronics engineer, and colleagues provided technical assistance to GSA including technical review of the control system design and specifications, laboratory testing of the BACnet™ capabilities of the products to be used in the building, and on-site commissioning support. Mr. Bushby and his colleagues also have been collecting and analyzing network traffic data to document how BACnet™ performs in large control systems. Phase II of the project, retrofit of the control systems for the air handling units and over 1,300 VAV box controllers, was completed in 1998 and the multivendor BACnet™ control system is fully operational. Phase III is under way and will expand the BACnet™ system to a new central plant facility and connect the control system in this building with other GSA buildings in Region 9 using BACnet™ over an Internet Protocol. This will provide centralized access to energy consumption and system performance data, and prepare GSA for aggregating utility loads in a deregulated marketplace.

Visual Test Shell (VTS) is a BFRL developed software tool for testing building control products for conformance to the BACnet™ standard. A revised version of this tool, which runs in a Windows95 or WindowsNT environment, was released in 1998. Development of the testing tool will continue in parallel with an ASHRAE addendum to the standard that defines conformance testing procedures for BACnet™.

BACnet™ work is expanding beyond the HVAC realm. BFRL is working with the National Electrical Manufacturers Association and the National Fire Protection Association to extend BACnet™ to fire protection products. The first commercial BACnet™ fire system products were introduced in 1998. New features are being added to the protocol that will enhance the use of BACnet™ in life-safety systems. For example, some day "smart elevators" may be able to tap into control systems so, if there is a fire, elevators can be used to help evacuate people in a safe and efficient manner. This is an example of industry's involvement and participation in the BACnet™ program that will lead to safer, more economical applications of automation in building systems.

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Standard Interface for Advanced Fire Alarm Systems

Mr. Richard Bukowski, research engineer, and staff of the Fire Safety Systems Group are working with the National Electrical Manufacturers Association (NEMA) and the fire alarm industry to advance the effectiveness of fire systems of the future. Such systems will be integrated with other building systems through the BACnet™ interface. They will provide active surveillance of all building features related to emergency functions to assure that they will operate as intended when needed. Thus, very high reliability will be achieved and reductions in the current high costs of preventive maintenance, typically seven percent of the total maintenance costs of buildings, will defray the increased cost of the advanced systems.

The systems also will use Fire Safety Engineering Division advanced fire models as a means to provide detailed data to the fire service that will enhance firefighter safety and improve operational effectiveness. One key aspect of this system is an improved fire service interface that will be standardized across the industry. This standard has been sought by fire departments to eliminate the current confusion with different interfaces on every system they encounter. Researchers from the Fire Safety Engineering Division have conducted two focus groups in conjunction with the International Association of Fire Chiefs to determine what they want to know, when they want to know it, and how to display information so it is easily understandable for making quick decisions. The results of these sessions are being used to develop prototype displays that will be tested further by the Phoenix, Nashville, and Atlanta Fire Departments. The National Fire Protection Association (NFPA's) National Fire Alarm Code Technical Correlating Committee established a Task Group to develop the standard for this interface, and NEMA's Signaling Division is providing cooperation and funding for this and several related tasks in this effort. All the major fire alarm manufacturers agreed to design and market products that will feature this interface.

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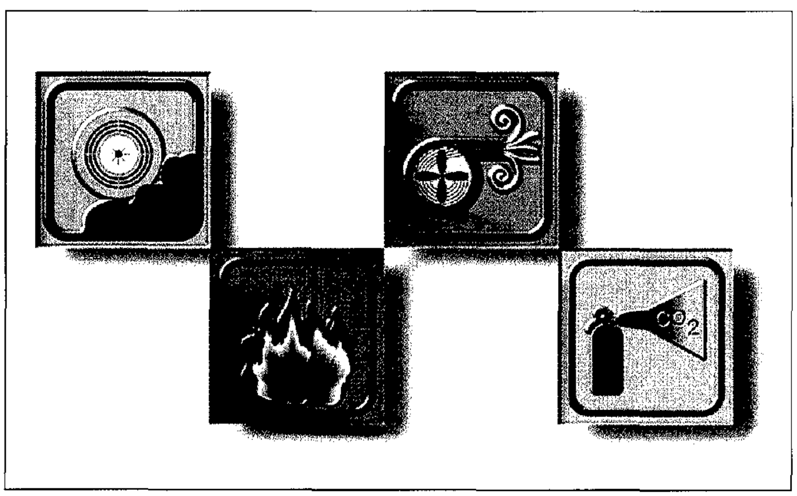
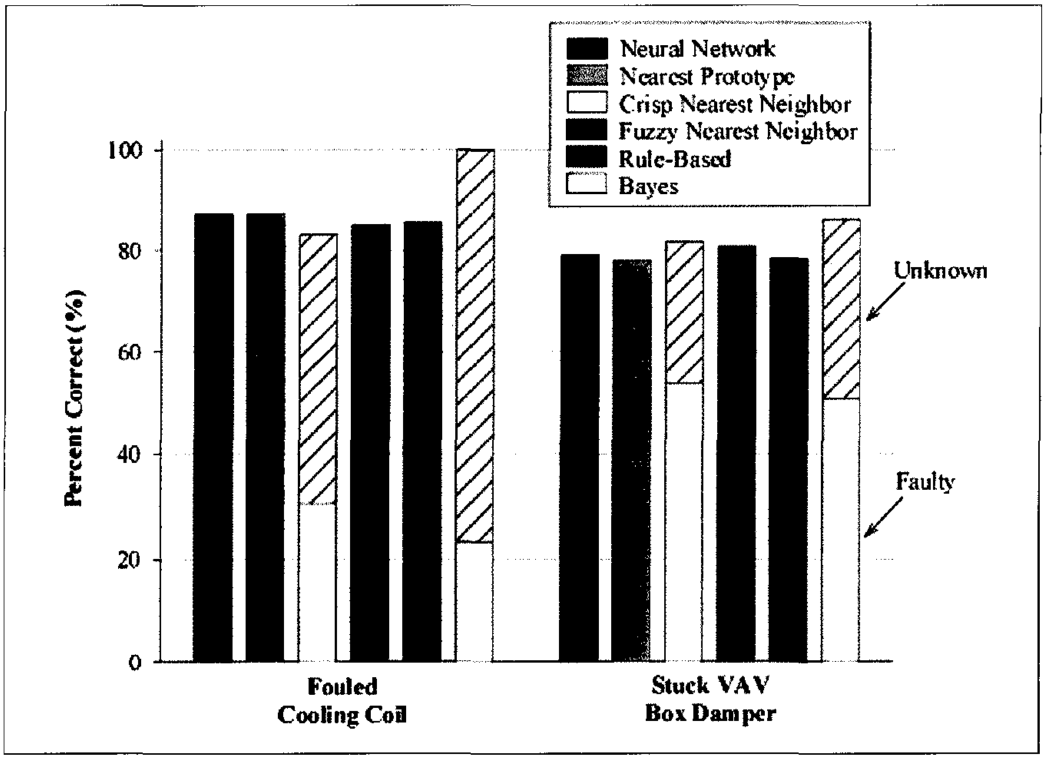


Key to a standardized display for fire alarm systems is a set of visual symbols for important system components and fire events.

Fire Detection Calibrator Comes on Line

The Fire Science Division is providing the measurement technology for the future of fire detection. Current smoke detectors provide a go/no-go signal in the presence of fire-generated particles. Unfortunately, similar aerosols are produced from other sources such as cooking and condensing shower steam. In residences, these nuisance alarms often lead householders to disregard real fire signals and

Shown are fault detection results of several classification techniques for two faults. The percent correct is taken to be the sum of the faulty and unknown classifications.



disconnect the sensors. In the cargo holds of commercial aircraft, nuisance alarms can force a pilot to undertake an emergency landing. Now, manufacturers are developing a new generation of fire monitors with two different features: they will contain more than one type of sensor and they will interpret the responses of the sensors. The Division staff, under the direction of Dr. William Grosshandler, leader, Fire Sensing and Extinguishment Group, have developed a device to measure the response of current and future fire product sensors. Built as a result of meetings with fire equipment manufacturers, the Fire-Emulator/Detector-Evaluator (FE/DE) is a laboratory wind tunnel that reproduces the fire environment that a sensor will experience. The FE/DE also can simulate the non-fire signals that can lead to nuisance alarms. Thus, a manufacturer can obtain data on sensitivity to the fires of concern and the stimuli to be ignored. These performance data on sensors of different types and designs will enable the industry to produce smart fire detectors both for stand-alone use and for integration into intelligent buildings, as well as transportation vehicles.

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Advanced Control and Diagnostic Capabilities for Air-Handling Units (AHU)

AHU controllers commonly use sequencing logic to determine the most economic use of the components within an AHU to maintain the supply air temperature at the setpoint value. Traditionally, split-range sequencing control strategies have been used for HVAC applications in which a single measured variable (e.g., supply air temperature) and feedback control loop are used to determine outputs to several controlled devices (e.g., heating coil valve, cooling coil valve, and mixing box dampers). Dr. Cheol Park, mechanical engineer, and Dr. John House, mechanical engineer, have collaborated with Johnson Controls, Inc. to perform simulation tests on a new finite state machine (FSM) sequencing control strategy for air-handling units. The FSM control strategy uses a separate feedback controller for each controlled component and provides straightforward logic for transitions between modes (states) of control. For cases in which the component feedback controller(s) are poorly tuned, the FSM control strategy yielded significant energy savings, improved temperature control, and reduced actuator use in comparison to the split-range control strategy. "A New Sequencing Control Strategy for Air-Handling Units", a paper in the January 1999 issue of the *International Journal of HVAC&R Research*, describes this work.

In the area of Fault Detection and Diagnostics, a paper "Classification Techniques for Fault Detection and Diagnosis of Air-Handling Units" was presented at the 1999 ASHRAE Winter Meeting in Chicago. In this study, neural network, nearest neighbor, nearest prototype, and Bayes and rule-based classification algorithms are used to assign simulation data to classes that consist of normal, faulty, and unknown operation. Further classification of faulty data helps localize the faulty behavior.

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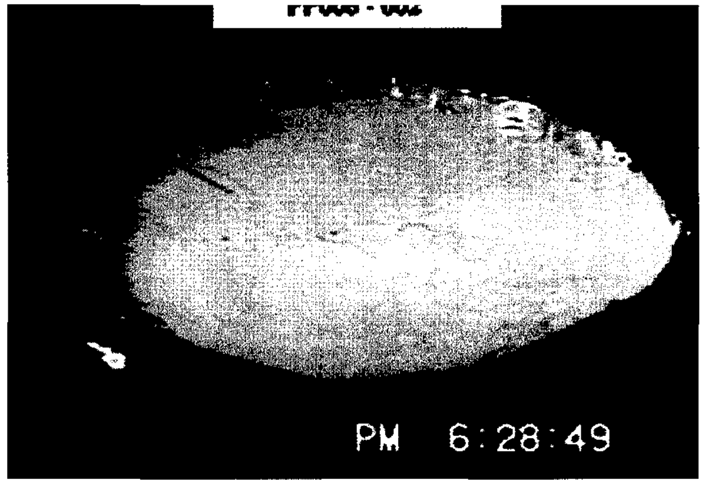
PP specimen showing large isolated bubbles, which, after a few minutes exposure, formed a relatively thin froth of very small bubbles



III

Fire Safe Materials

Intended Outcome. *Validated technology for the U.S. plastics industry to assure that modifications to their products will manifest the intended fire performance without significant reduction of their physical properties, resulting in new/improved U.S. products for domestic and international markets. A first case will be demonstrated in FY 2000, and a general protocol will be completed by FY 2002. The BFRL product will be a model of the burning of a bench-scale sample of a material based on scientifically sound principles that are capable of implementation by industrial chemists and demonstrated to be accurate at predicting improvements in fire performance at real, end-product scale.*

Nanocomposites: a New and Effective Approach to Fire Retardancy

In the pursuit of improved approaches to fire retarding polymers, a wide variety of concerns must be addressed in addition to the flammability issues. For commodity polymers, their low cost requires that the fire retardant (FR) approach also be of low cost. This limits solutions primarily to additive type approaches. These additives must be inexpensive and easily processed with the polymer. In addition, the additive must not excessively degrade the other performance properties of the polymer, and it must not create environmental problems during recycling or at the time of its final disposal.

Dr. Jeffrey Gilman, research chemist, Dr. Takashi Kashiwagi, leader, Materials Fire Research Group, and co-workers have demonstrated that polymer layered-silicate (clay) nanocomposites may fulfill the requirements for a high-performance additive type flame retardant system for polymers; i.e., one that reduces flammability while improving the other performance properties of the final formulated product. Dr. Gilman, in collaboration with Dr. Cathryn Jackson of the Polymers Division of the NIST Materials Science and Engineering Laboratory, has used x-ray diffraction and transmission electron microscopy to characterize the high-performance carbon-silicate multilayer char structure responsible for the significant improvement in flammability which results from as little as 2 percent clay in the nanocomposites. This work has generated international interest and a consortia of eight companies and three government agencies was formed to study the nanocomposites' flame retardant mechanism.

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Understanding How Polymers Really Burn

Developing new principles for reducing the flammability of plastics requires knowledge of the detailed processes these materials undergo during burning. Dr. Thomas Ohlemiller, chemical engineer, and Mr. Kenneth Steckler, physicist, have completed a series of degradation/gasification experiments on commodity polymers polypropylene (PP), polyethylene (PE), and polystyrene (PS). In the Fire Science Division's gasification apparatus, specimens (100 mm diameter, 25 mm thick) were exposed to a radiant flux of 40 kW/m^2 in a nitrogen atmosphere, and the gasification (mass-loss) rate and temperatures within the specimens were measured. Direct observation of PP revealed that bubbles, which at the beginning of the experiment were large and isolated on the specimen's surface, eventually formed a froth of very small bubbles, very similar in appearance to that of a beer "head." The gasification process was dominated by this bubbling-surface behavior. Similar results were obtained for PE. In the case of PS, however, the melt viscosity appeared to be greater, and the bubbles in the "froth" were somewhat larger than those observed for PP and PE. The temperature traces for PP and PE, as well as mechanical probing of their froths, revealed that the froth thicknesses were relatively thin; from one to a few bubble diameters. Accordingly, Dr. Ohlemiller and Mr. Steckler suggest that for modeling purposes, these materials be treated as three layers: a top layer of bubbles, relatively thin and isothermal; a melt layer whose temperature decreases with depth, and a solid bottom layer whose temperature decreases with depth.

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Modeling Burning Plastics

To help plastics formulators improve the fire behavior of their products, a model of burning behavior needs to relate the material chemistry and the physical changes to the tested properties, most importantly the rate of heat release. For many thermoplastic materials, chemical degradation is accompanied by the development of an active layer of bubbles that grow, migrate, and burst in the melted region near the surface. Dr. Kathryn Butler, physicist, completed a one-dimensional model of pyrolyzing thermoplastic materials that considers the bubble motion to be sufficiently vigorous to thoroughly mix the uppermost layer of melt. The model includes in-depth gasification, a melting phase change, radiative and convective heat losses at the surface, and substrate thermal properties. The results are being compared with those from an identical model that does not include bubble effects to determine the importance of this phenomenon. Inclusion of the transport of gases through the material and the impact of bubbles on thermal conductivity also is under way.

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Gas Phase Modeling: Polymer Burning in Cone Calorimeter

To better understand the fire safety characteristics of materials, Dr. William Mell, mathematician, is developing a model that simulates the ignition and burning of a solid in a cone calorimeter apparatus. Companion experiments involving commodity polymers in the cone calorimeter also are under way to help validate the model. The gas phase model, which includes the flame and heated cone, provides the net heat flux on the surface of the condensed phase. This heat flux is an input to the condensed phase model and drives thermal degradation and the production of gaseous fuel. The rate of gaseous fuel production, in turn, is input into the gas phase model and controls flame development.

Today's computers are not sufficiently powerful to simulate the component processes involved in the ignition and subsequent growth of the flame. Hence, the gas phase calculation is based on a large eddy simulation approach developed by Dr. Howard Baum, NIST Fellow, and Dr. Kevin McGrattan, mathematician, for simulating large fires. This approach simplifies the governing equations by approximating the flame as a large number of burning thermal elements. The physical structure of the cone calorimeter can be easily included in the simulation. The dominant component of the heat flux onto the solid phase is due to thermal radiation (mainly from the heated cone). The model used for thermal radiation includes the effects of absorption in the gas phase.

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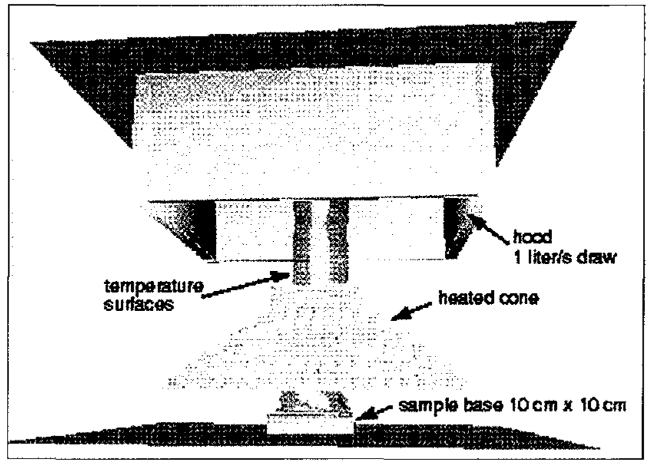
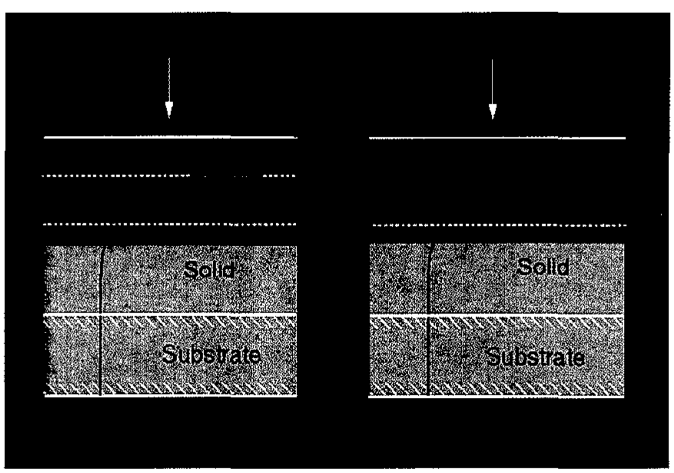


Geometry of simulated cone calorimeter apparatus. The dimensions of the domain are 60 cm on a side and 40 cm high. The cells comprising the cone are delineated by white lines. Two levels of temperature, due to the hot products, are shown as dark (160°C) and lighter (60°C) greyscale.



In-depth gasification models with and without a mixed layer representing bubbles. Temperature profiles are outlined in black, and production of volatile gases is indicated by shaded regions.

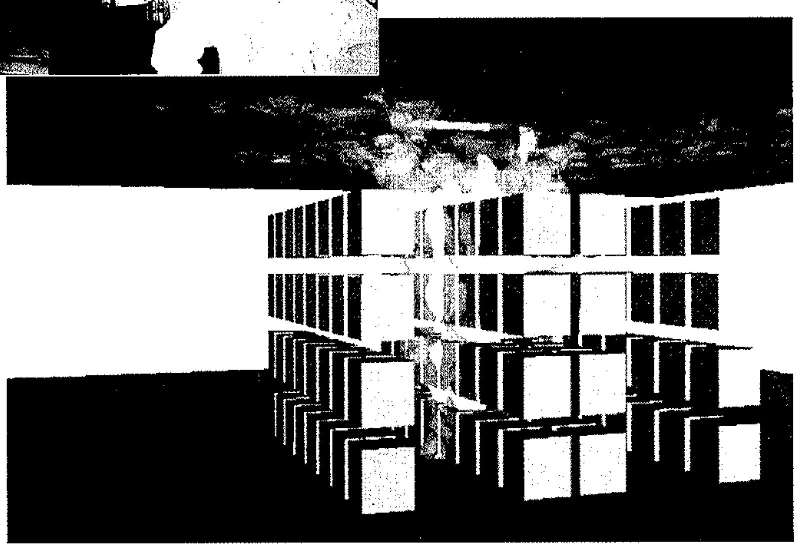
IV

Industrial Fire Simulation System

INTENDED OUTCOME. *A shift from fire safety determined predominately by information from large scale testing to reliance on information from verified computer simulations of industrial fire events. Accurate, accessible, and easily understood fire simulations will create for the first time a means to routinely demonstrate the relationship of fire safety costs and expected losses on an individual facility and specific fire scenario basis. Drawing on experience with large eddy simulation (LES) technology used to predict the characteristics of smoke plumes from industrial fires, a second industrial fire simulation (IFS2) will be developed to generate predictions of fires in facilities protected by automatic fire sprinklers. IFS2 is a LES-based fire simulation, with specified means of input data measurement, and a system to gather electronically input data from data bases and deliver the results of the simulation. IFS2 will be operational with at least one industrial partner by 2000 and in use by 2003. In pursuing this objective, BFRL actively partners with fire sprinkler manufacturers, the insurance industry, the U.S. Council for Automotive Research, the University of Maryland, and the University of Michigan.*

Interaction of Sprinklers, Draft Curtains, and Roof Vents

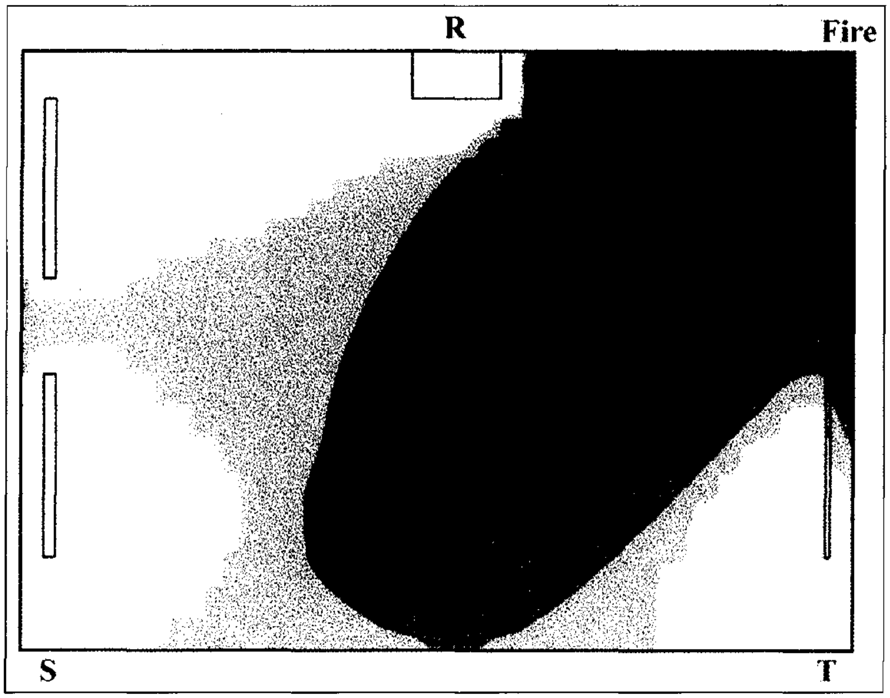
Dr. David Evans, chief, Fire Safety Engineering Division and coordinator of BFRL's research in this area and industrial partners, brought together by the National Fire Protection Research Foundation, have quantified the interaction of sprinklers with an industrial storage fire. Research centered on measuring the interactions of sprinklers, draft curtains, and heat and smoke roof vents in controlled tests involving the burning and suppression of a high piled boxed plastic commodity, and developing fire simulation methods. Data from five large scale fire tests in which the high stacked commodity was burned and 32 tests with controlled fires from gas burners were used to evaluate the interactions of the fire protection systems and developed and verified the computer model. Results of the study are published in the NIST report, *Sprinkler, Smoke and Heat Vent, Draft Curtain Interaction — Large Scale Experiments and Model Development,* NISTIR 6196-1 by Kevin McGrattan, Anthony Hamins, and David Stroup. For the well controlled gas burner tests, the fire simulations based on BFRL's industrial fire simulation (IFS) model were capable of predicting the activation times for the first ring of four sprinklers immediately near the ceiling directly above the ignition point to within 15 percent of the measured time and 12 additional sprinklers in the second ring to within 25 percent. The goal of developing a simulation capable of predicting whether an industrial fire would be controlled by the activation of a large or small number of sprinklers was satisfied. The high resolution IFS fire model is supported by sub-grid phenomena models for sprinkler sprays and burning rates of boxed plastic commodity. Results of the IFS calculations can be viewed as full motion video simulations of the fires. Such simulations are building wide spread acceptance and excitement for the technology. Presenting the findings as a video simulation, the agreement between



Dr. Kevin McGrattan, mathematician, the developer of the computer simulation, is observing a fire conducted in the Large Fire Test Facility, Underwriters Laboratories. Insert, BFRL large eddy simulation of a Group A Plastic fire experiment.

Large Photo is courtesy of Underwriters Laboratories Inc., Northbrook, IL.

The photograph illustrates smoke detector activation time when located at a standard depth beneath the ceiling. Note, the activation time for the HVAC supply ducts (denoted by S&T) and the HVAC return ducts (denoted by R) are in locations that lack timely smoke detector response. The white areas illustrate an activation time greater than 80 seconds. Blue represents 20 seconds or less and orange illustrate activation time between 65 and 80 seconds.



the modeling and experiments for major features of large scale tests is easily demonstrated to the viewers.

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Simulating Design Complexities on Fire Detector Response

BFRL recently completed research on the application of computational fluid dynamics models to perform computational experiments that explored the impact of complex ceiling arrangements and HVAC system layouts on the response of simulated fire sensors at various locations. This research, led by Mr. Richard Bukowski, research engineer, was sponsored by the National Fire Protection Research Foundation and a number of public and private organizations. The findings of this work will improve the technical basis for locating heat and smoke sensing equipment in areas with complex ceiling geometries and high ventilation rates. The research provided quantitative information on detector and sprinkler response to fires in spaces constructed with beamed and sloped ceilings and on the effects of heating, ventilating, and air-conditioning (HVAC) flows on fire and smoke spread. The research revealed a potential problem with the current practice of placing detectors near return air openings. There is an area near the returns where the response of the detectors was delayed significantly, especially in open plan rooms, common in commercial office buildings (see photo). The model further showed that locating detectors near the ends of slot diffusers gave delayed response. This research has contributed to a better understanding of the importance of smoke and fire detector placement in buildings with complex ceiling arrangements and high HVAC flows. The results have replaced rule-of-thumb guidelines about installing detectors near HVAC registers, and the findings could lead to improvements in the fire codes and standards that protect life and property.

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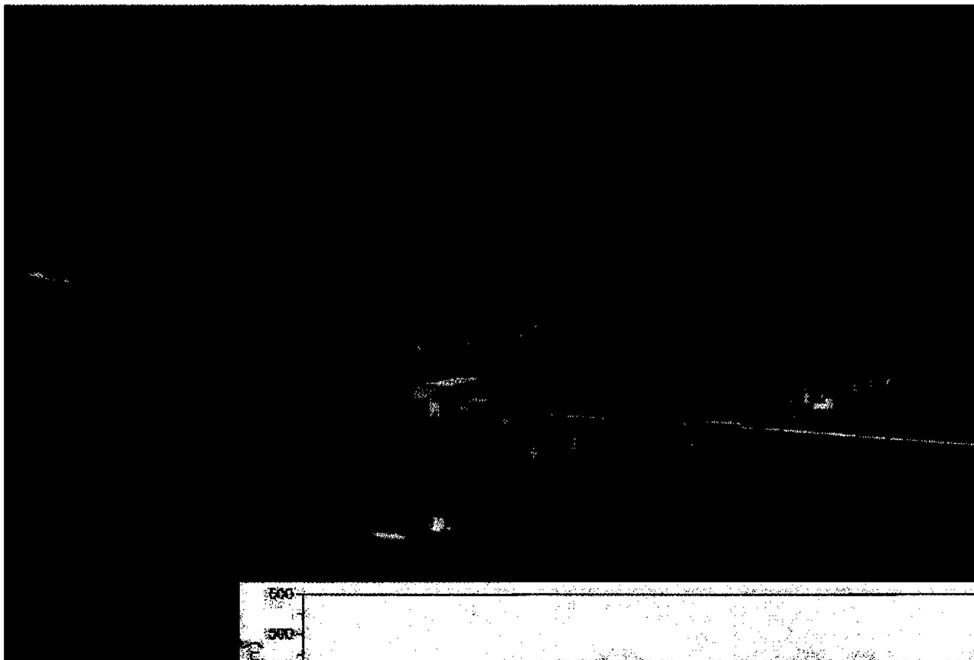
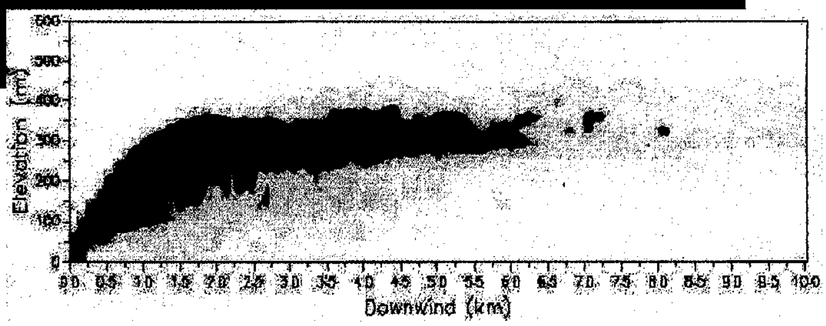
Smoke Aloft™

Large outdoor fires generate smoke plumes that may be of concern to nearby populations. Mr. William Walton, senior fire prevention engineer, and Dr. Kevin McGrattan, mathematician, have developed a computer-based model that predicts the downwind distribution of smoke particulate and combustion products from large outdoor fires such as burning spilled crude oil. The model, called ALOFT-FT™ (A Large Outdoor Fire Plume Trajectory-Flat Terrain) is a public domain PC-based version of the Large Eddy Simulation (LES) plume trajectory models developed earlier by the Fire Safety Engineering Division that predicts downwind smoke concentrations for flat and more complex terrain.

ALOFT-FT™ was developed to help decide if intentional burning is a viable method for cleaning up an oil spill. Over the recent past, ALOFT-FT™ has been refined, and the results have compared favorably with the limited data from experimental burns. ALOFT-FT™ uses fuel type, fire area, and wind conditions to model the downwind





Aerial photograph of an experimental crude oil burn, North Slope, Alaska, 1994. The insert is ALOFT-FT™ prediction of downwind smoke concentration.

distribution of smoke and other combustion products. The output can be displayed, using a graphical user interface, as downwind, crosswind, and vertical concentration contours. Although ALOFT-FT™ was developed as a user-friendly tool to help analyze intentionally created burning oil spills, it also may be useful to the fire service in responding to industrial fires. Further information on ALOFT-FT™ can be found on the World Wide Web at http://flame.cfr.nist.gov/aloft/

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Simulating Oil Tank Fires

Industrial fires are usually localized but intense emitters of heat, smoke, and other combustion products especially if the fuel is a petroleum-based substance, with a high-energy density and sooting potential. The hazards associated with such fires occur on two widely separated length scales. Near the fire, over distances comparable to the flame length, the radiant energy flux can be sufficiently high to threaten the structural integrity of neighboring buildings and the physical safety of firefighters and plant personnel. At much greater distances, typically several times the plume stabilization height in the atmosphere, the smoke and gaseous products generated by the fire can reach the ground in concentrations that may be unacceptable for environmental reasons. This latter issue led to the development of a Fire Safety Engineering Division computer model, ALOFT (A Large Outdoor Fire Plume Trajectory), which is available at http://flame.cfr.nist.gov/aloft/.

Dr. Howard Baum, NIST Fellow, and Dr. Kevin McGrattan, mathematician, developed methods to simulation industrial scale fires with the properties of local atmosphere and the built environment into a single simulation. In their scenario, a fire is on top of an oil storage tank adjacent to several neighboring tanks. This scenario was chosen for its intrinsic importance and because it illustrates the ingredients needed to generate a realistic simulation of such an event. The heat release generated by a fire on this scale can reach several gigawatts if the entire pool surface is exposed and burning. Such fires interact strongly with the local topography (both natural and man made), and the vertical distribution of wind and temperature in the atmosphere. Moreover, the phenomena are inherently time dependent and involve a wide temperature range.

The Japan National Oil Corporation invited Dr. Baum to advise them of his simulation models at their large-scale fire experiment of an oil storage facility at Tomakomai, Japan. The Tomakomai site consists of 80 crude oil tanks; each tank is 84 meters in diameter and 26 meters high. Japanese researchers at the National Research Institute for Fire and Disaster (NRIFD) made predictions using the ALOFT simulation and the results were demonstrated to be in close agreement with the observed fire plumes.

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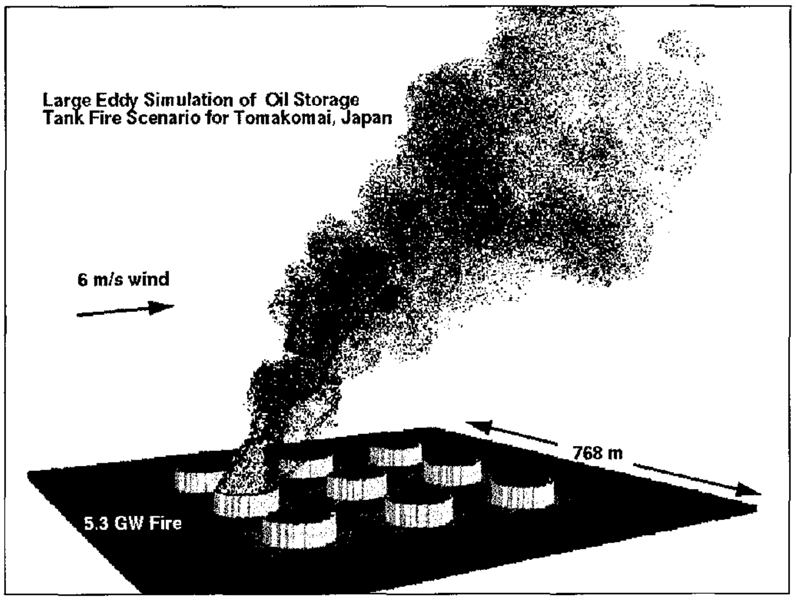
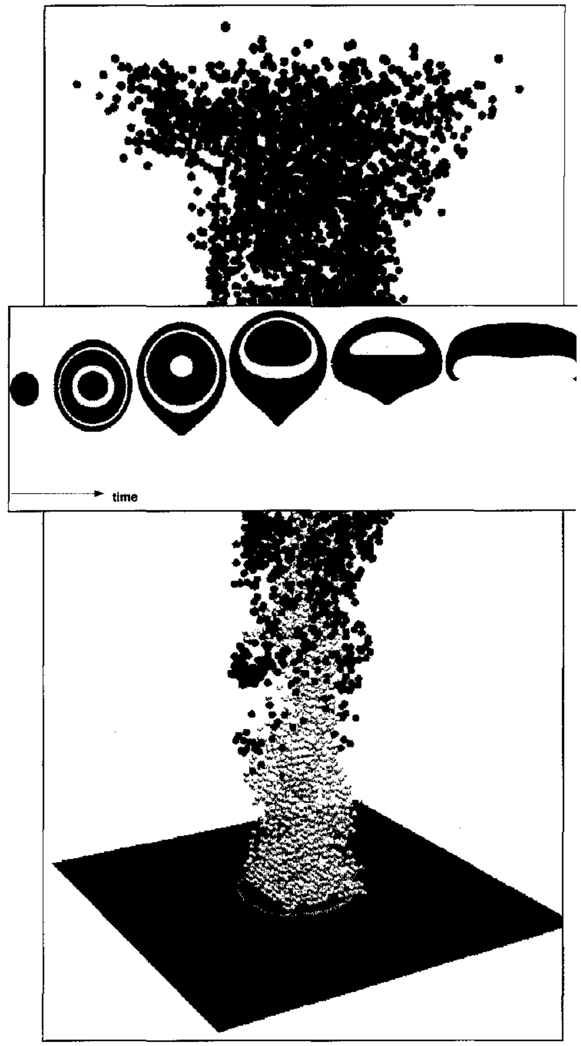
Computer simulation of a segment of the Tomakomai oil storage facility, one of the 10 national oil storage facilities that make up Japan's 120-day reserve.





Pool fire simulation with a plume of hot (yellow) and burned-out (black) thermal elements; net radiative flux on the floor is color-contoured. The insert shows the time evolution of a burning thermal element with color-contoured temperature levels.

Thermal Radiative Model for Fire

Thermal radiation is the dominant mode of heat transfer in large fires. By transferring heat radiatively, a large fire can ignite objects which are not in contact with the flames. This can result in a rapid fire growth and has important fire safety consequences. Incorporating accurate and efficient radiation models in fire simulations presents a critical challenge to fire researchers.

One of the Fire Safety Engineering Division's approaches in fire simulation modeling is called the large eddy simulation (LES) model. Three-dimensional fire simulations for present day workstations are constructed by simplifying the governing equations. Division researchers Dr. Howard Baum, NIST Fellow, and Dr. William Mell, mathematician, have developed a model of radiative transport in fires that can be used in the LES model.

The LES model distinguishes between physical phenomena that can be resolved on a computational grid and those that operate at scales too small to resolve (subgrid). An analogous strategy is used to model the thermal radiation generated by a fire. For example, the velocity and temperature fields are resolved, but combustion and radiative emission occur at subgrid scales. The energy released by combustion is accounted for by "hot" thermal elements, which move with the buoyancy-induced flow. The time history of the energy release associated with a thermal element is computed separately or prescribed on the basis of experimental results. The final radiation model will be incorporated into the industrial fire simulation (IFS) code currently being developed by the Division.

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V

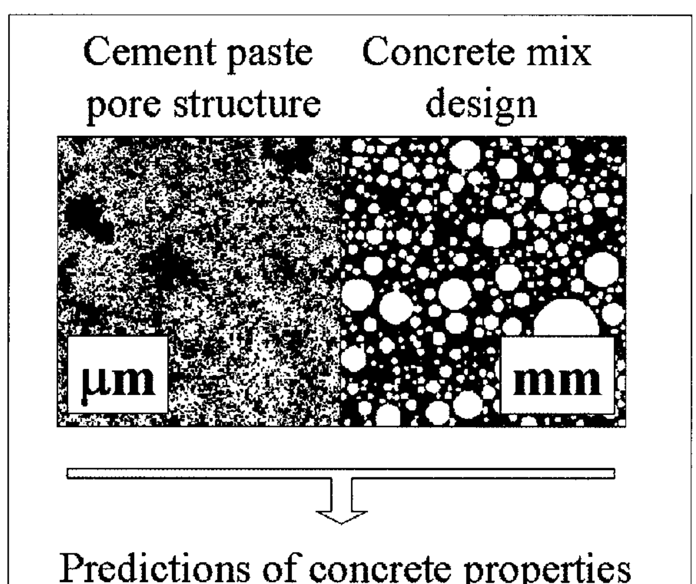
Partnership for High Performance Concrete Technology

Intended Outcome. *In partnership with industry, enabled the reliable application of high-performance concrete (HPC) in buildings and the civil infrastructure by developing, demonstrating, and providing assistance in implementing a computer-integrated knowledge system, HYPERCON, incorporating verified multiattribute models for prediction and optimization of the performance and life-cycle cost of high-performance concrete. The BFRL product will be the deployment of the computer-integrated knowledge system, HYPERCON, in a commercial HPC construction project by 2002. BFRL partners with many organizations in this objective, including: National Ready-Mixed Concrete Association; Portland Cement Company; Master Builders, Inc.; W.R. Grace Company; Federal Highway Administration; U.S. Army Corps of Engineers; Nuclear Regulatory Commission.*

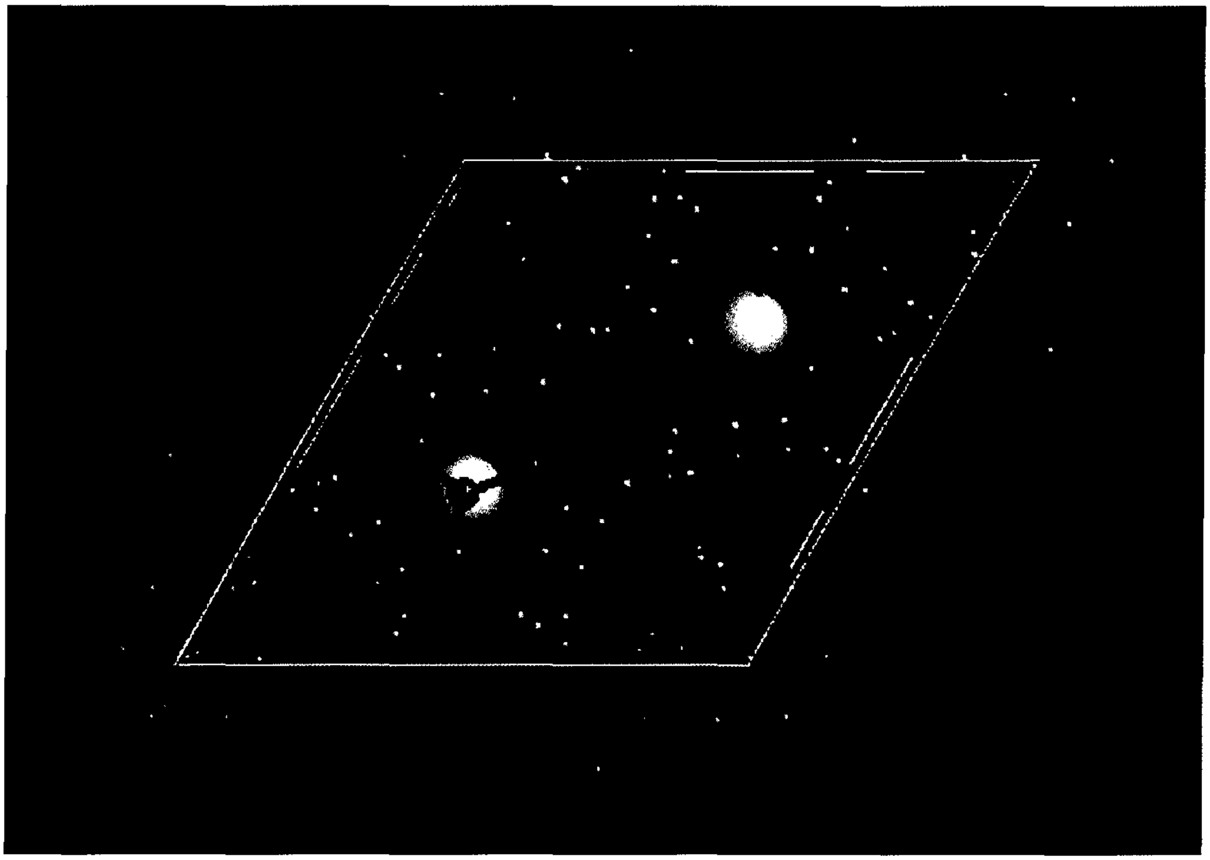
Concrete is used in larger quantities than any other manmade construction material. Recent advances in the knowledge of material science of concrete have shown that there are substantial opportunities for improvement in its durability, placeability, and strength if the appropriate measurement methods and predictive tools can be developed and standardized. BFRL researchers are providing the technical basis for the measurement methods and predictive tools that will help the construction industry exploit these opportunities. Examples are described.

Simulating the Performance and Service Life of HPC

The service life of high-performance concrete (HPC) depends on properties such as resistance to penetration by water and aqueous solutions and dimensional stability. Needed are quantitative prediction methods so HPC can be designed for service life and life-cycle cost, not just strength. These predictive methods must be based on fundamental material science and take into account micro-structure, cement chemistry, concrete mixture design, and expected curing rate. Dr. Edward Garboczi, physicist, has developed a computer model for predicting the microstructure of cement paste. He is revising the percolation and diffusivity aspects of the pore structure predictions of the cement-paste model, which will lead to improvements in the associated chloride diffusivity model. Dr. Garboczi and co-division collaborators, working with Lawrence Livermore Laboratory, have improved the effective medium theory of the cement paste model, which enables the user to avoid supercomputer computations. By a multiscale approach, a chloride diffusivity model has been developed permitting the prediction of the service life of reinforced concrete exposed to deicing salts and seawater.



The schematic illustrates how models of pore structure and mix design are used to link together cement paste (micrometers) and concrete (millimeters) into a multiscale prediction of the properties of concrete.



Development of a new ASTM standard test method using Rietveld analysis of X-ray powder diffraction patterns involves calculating a set of best-fit diffraction patterns based upon a refined crystal structure model. A database of cementitious materials structures is being developed to facilitate this method.

In a related effort, Dr. Garboczi collaborated with partners in the NSF Center for Advanced Cement-Based Materials (ACBM) in developing a 12-minute educational video on microstructure development in concrete. The video highlights the importance and structure of the interfacial transition zone which has a profound influence on the diffusivity of concrete. This is the fourth in a series of educational videos distributed by the ACBM. An electronic monograph on "Modeling the Structure and Properties of Cement-Based Materials," that has grown to be the equivalent of a 1,000-page book, is available from http://ciks.cbt.gov/garboczi/.

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Micro- and Macro-Structural Characterization of High-Performance Concrete

Application of material science to concrete requires the ability to determine and describe its micro- and macro-structures. There is a need to develop a methodology for quantitative characterization of the micro- and macro-structural features that determine the effects of processing and environmental effects on the performance and service life of concrete. Mr. Paul Stutzman, physical scientist, has developed a method to characterize the micro- and macro-structures of HPC. This method is being applied in projects investigating the response of HPC to fire and the effects of processing on HPC structure and performance. Mr. Stutzman has used quantitative image analysis extensively in developing improved techniques for advancing concrete petrography, and he is applying the techniques to evaluate material heterogeneity and obtain evidence of deleterious physical and chemical processes. Also, he produced analytical methods for characterizing cements and associated materials. Interactions with cement manufactures and government laboratories have been established through ASTM Committee C01 on Cement. This work has demonstrated that modeling of X-ray powder diffraction patterns of cementitious materials and hydration products can provide needed phase, chemical, and crystal structural information (see photograph). This data will aid in the selection of cements for HPC and in the understanding of their performances.

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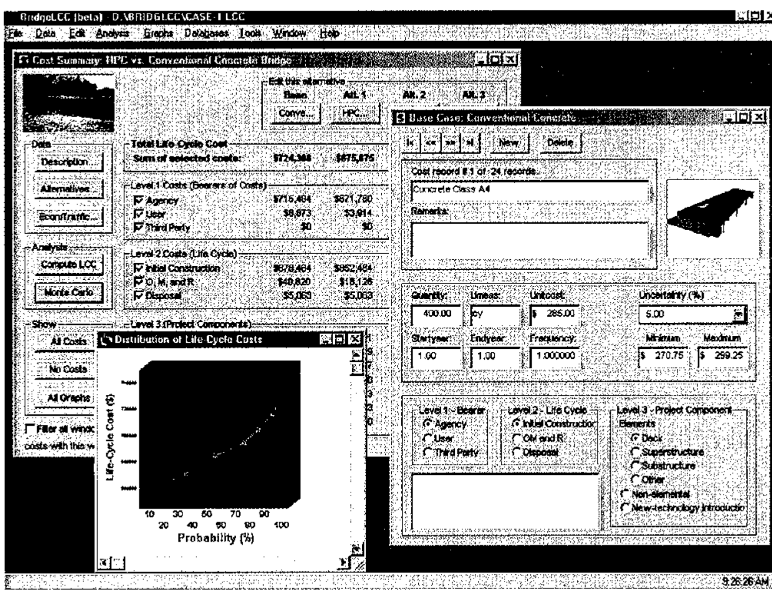
Economic Software for Assessing the Life-Cycle Costs of Highway Bridges

Dr. Mark Ehlen, industrial economist, completed BridgeLCC 1.0, user-friendly Windows software for evaluating the life-cycle costs of highway bridges. Based on an economic model developed by Drs. Ehlen and Harold Marshall, chief, Office of Applied Economics, BridgeLCC is specifically designed to compare bridges constructed with high-performance materials, such as high-performance concrete and FRP composites, with those using conventional construction materials. The software includes a BFRL-developed service life prediction tool, a Monte Carlo module for analyzing uncertain costs, and a proposed standard bridge elemental classification that is consistent with the American Association of State Highway Transportation Officials (AASHTO) bridge management system software. Dr. Ehlen is working with the Federal Highway Administration and AASHTO to implement BridgeLCC at state departments of transportation. The software gives State agencies an evaluation tool to help them recognize when they can reduce the costs of building and repairing bridges by using new, higher-performance materials.



BridgeLCC can address the inherent cost uncertainties of structures built from new technology construction materials.

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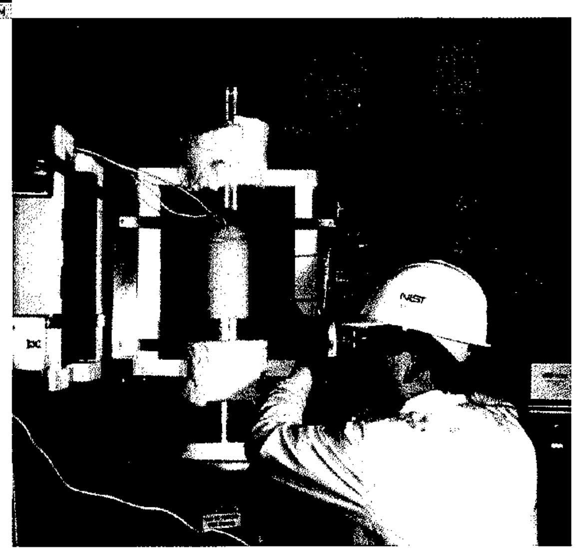
Fire Performance of High-Strength Concrete

As part of a continuing effort to assist U.S. industry in the safe, economical, and widespread use of high-strength concrete (HSC) in construction, the Division published the proceedings, *International Workshop on Fire Performance of High-Strength Concrete, NIST, Gaithersburg, MD, February 13-14, 1997,* (Phan, Long et al.), NIST Special Publication 919, and an article "Review of Mechanical Properties

Dr. Long Phan, research structural engineer, at test setup for measuring material properties of HSC at elevated temperatures.



of HSC at Elevated Temperature" (Phan, Long and Carino, Nicholas), *Journal of Materials in Civil Engineering*, American Society of Civil Engineers, 1998. The authors concluded that HSC has significantly shorter fire endurance times than normal-strength concrete (NSC) and is more susceptible to spalling in fire exposures; there are inadequate data to model the temperature-dependent properties of HSC; and existing fire design standards are based on data for NSC and are not applicable for HSC.

To address these issues, Dr. Long Phan, research structural engineer, initiated a comprehensive multiyear project in FY 1998 to study the mechanical, thermal, and transport properties of HSC at elevated temperatures. Dr. Phan and colleagues from BFRL's Building Materials, Fire Safety Engineering, and Building Environment Divisions are developing analytical tools for assessing the fire performance of HSC and techniques to improve the fire performance of HSC. The research findings will be deployed in developing HSC fire design standards.

BFRL and the Portland Cement Association (PCA) signed a Cooperative Research and Development Agreement to develop an experimentally-validated analytical model for predicting the fire performance of HSC. Under the agreement, BFRL will use and partner with PCA to improve an existing PCA-developed heat and mass transfer model.

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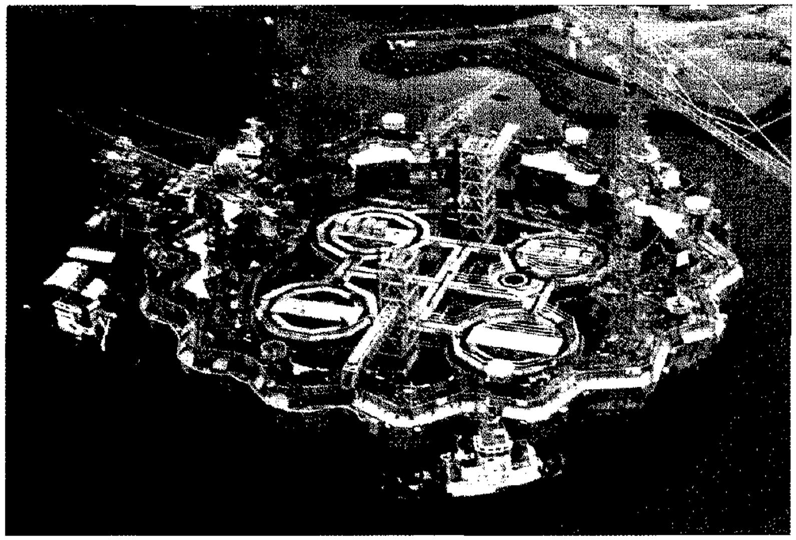

Photo courtesy of Hibernia Management and Development Company Ltd., St. John's, Newfoundland

Portions of the Hibernia gravity-based platform structure were designed using the modified compression field theory.

Design Requirements for High-Strength Concrete Under Shear Loads

The American Concrete Institute's (ACI) design provisions for concrete structures under shear loading is based on a simplified model, the use of which is limited by the range of concrete strengths and properties of the reinforcement, i.e., steel used in the empirical data base used to calibrate the model. The increasing use of higher-strength concrete, a more brittle material, and the potential use of fiber-reinforced polymer composite shear reinforcement, prompted the Structures Division to conduct a study to identify and review selected alternative models for the shear resistance of reinforced concrete beams, specifically theory-based models that do not require empirical correction factors. Dr. Dat Duthinh, research structural engineer, led the study.

Among the several factors considered in reviewing alternative theories were: 1) the agreement with experimental data; 2) the complexity of the theory; 3) completeness; and 4) prior user experience with the theory. Based on the review and a follow-on parametric study, it was found that the Modified Compression Field Theory (MCFT), developed at the University of Toronto, best met the competing requirements. The theory is applicable to any combination of concrete strengths and type of reinforcement and can be simplified for use through design charts and tables. The study concluded that the MCFT was a good candidate to suggest as an alternative to the current ACI design requirements. Draft code provisions were prepared and submitted to the ACI Shear and Torsion Committee for code adoption.

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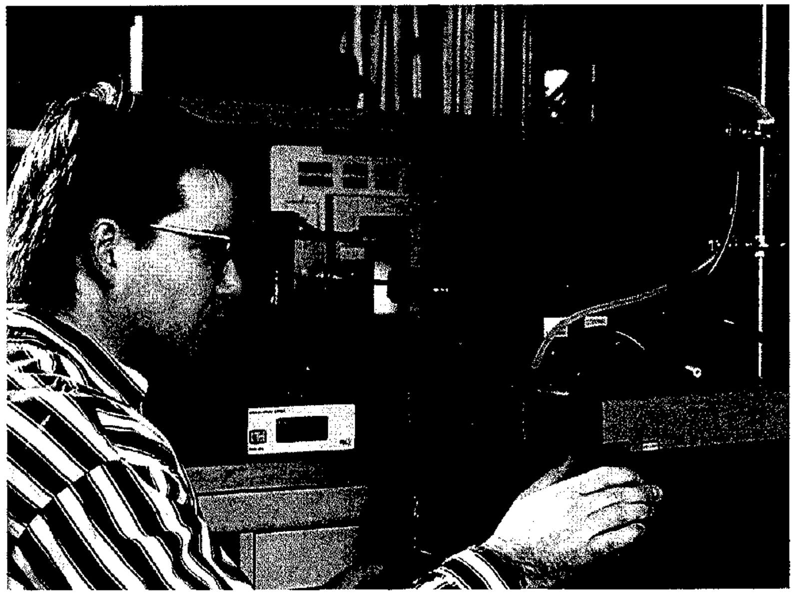
VI

Performance Standards System for Housing

INTENDED OUTCOME. *Increased opportunities for innovation and enhanced competitiveness by working with the U.S. housing industry in developing: 1) performance standard guides for housing nationally and internationally and 2) data and tools to advance industry's capabilities in setting performance criteria and in evaluating, measuring, and predicting performance of housing. The BFRL product will be a suite of industry supported, national and international housing performance standards developed within the American Society for Testing and Materials (ASTM) and the International Organization for Standardization (ISO), respectively. The first ASTM approved guide standard is targeted for 2000. Enhanced tools (analytical models and related databases) will emerge beginning in 2001.*

Predicting Indoor Environments

Dr. Andrew Persily, leader Indoor Air Quality Group, and Division researchers are validating methods for predicting specific airborne contaminant distributions and thermal comfort parameters. Because measuring ventilation rates, contaminant concentrations, and thermal comfort parameters in any significant number of buildings is prohibitively expensive, compliance with indoor environmental criteria will involve the use of predictive methods. The predictive methods will use building ventilation and indoor air quality models based on the Building Environment Division's CONTAM model. Before a CONTAM-based compliance approach can be incorporated into a performance standard, its predictive reliability must be demonstrated through experimental validation, and the program must be made accessible to those implementing the performance standard. A test facility was instrumented to obtain additional data needed to validate the CONTAM-based evaluation method.



Mr. Steven Emmerich, mechanical engineer, prepares particle monitoring equipment for field tests to validate indoor air quality models for predicting the performance of residential air filtration devices.

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Economic Support for Performance Standards System for Housing

Standard economic methods and software help decision makers in the housing industry choose the most cost-effective designs, materials, and equipment that satisfy housing performance standards. Dr. Robert Chapman, economist, and other researchers are developing a benefit and cost classification format that will help decisionmakers identify potential benefits and costs from alternative design, material, and system selections. In addition, the researchers will identify and illustrate, in case examples, methods for evaluating those economic benefits and costs of alternative housing designs, materials, and systems. To assure industry acceptance, the methods are being made consistent with ASTM's published standard methods on building economics. The two methods being emphasized are the life-cycle cost (LCC) method, which helps the user select the least-cost alternative that meets the performance standard, and the analytical hierarchy process (AHP) method, which allows the user to consider qualitative and quantitative (non-monetary) data in addition to LCC data in choosing the best technology. Case illustrations of how to use the LCC and AHP methods in seeking the optimal alternative to meeting a housing performance standard will be submitted to ASTM to be included in ASTM standards.

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Structural Safety and Serviceability Performance Standards

Dr. John Gross, leader, Structural Systems and Design Group, developed a performance-based pre- standard guide for one- and two-family dwellings that addresses the attributes of structural safety and serviceability. The guide is one of a set of standard guides for specifying and evaluating the performance of housing. The guide provides a method to exploit a performance-based standards system for procuring and evaluating housing that will more readily allow for, and encourage, use of innovative designs, products and processes leading to improved quality, lower life-cycle costs of housing, and increased competitiveness for U.S. companies. Through his work with ASTM Committee E06.66 on Performance Standards for Dwellings, Dr. Gross helped establish a Task Group on Structural Safety and Serviceability which is in the process of developing the guide into a consensus standard. The present prescriptive system for regulating housing construction is a primary barrier to innovation and limits competition both nationally and internationally. The need for a performance standards system for housing is a priority component of the Residential Sector Strategic Approach aimed at meeting the National Construction Goals.

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VII

Service Life of Building Materials

Intended Outcome. *Developed the scientific and technical basis for implementing a service life prediction methodology that decreased the time-to-market and life-cycle risks for building materials and established a technology transfer infrastructure for the rapid dissemination and utilization of the developed methodology. The BFRL product will be a standard practice for reliability-based service life prediction of organic building materials.*

Tape-Bonded Seams for EPDM Single-Ply Roofing Systems

Dr. Walter Rossiter, research chemist, completed a three-phase, three-year industry/government consortium aimed at comparing the performance of tape-bonded and liquid-adhesive-bonded seam joints of EPDM (ethylene-propylene-diene terpolymer) roofing membranes. EPDM roofing is installed in about one-third of commercial low-sloped roofs in the United States and leak-free seams are critical to its performance. Liquid adhesives, available since the mid-1980s, have performed satisfactorily and represent the benchmark against which the performances of new adhesives are compared. The use of tape adhesives, which offer environmental and economic benefits, has increased since the early 1990s. The consortium included representatives from tape manufacturers, membrane manufacturers, and roofing contractor and consultant associations. The tape-bonded seams performed as well as or better than liquid-adhesive-bonded seams in the testing performed. A concurrent field investigation indicated that performance to date has been very satisfactory. The results of the consortium have hastened the acceptance of tape-bonded seams in practice.

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Methodology and Metrologies for Predicting the Service Life of Coating Systems

Dr. Jonathan Martin, leader, Organic Building Materials Group, and Dr. Tinh Nguyen, physical scientist, completed the first three-year phase of an industry/

Dr. Mark Van Landingham, materials research engineer, and Ms. Amanda Grasso, student, prepare a specimen for dynamic mechanical analysis. DMA characterization of tape adhesives was used in the consortium study.

Mr. Michael Galler, student, is using a confocal microscope to optically slice through a pigmented coating system to image the microstructure of a coating.

government/university consortium on the service life of coating systems and began a second three-year phase in January 1998. The goal of the consortium is to establish the link between outdoor and laboratory-exposure results for coatings. Accomplishments of the first three-year phase included the development of an advanced optical exposure device and humidity generator that can independently control the temperature, relative humidity, and incident spectral ultraviolet radiation within narrow bounds; delineation and tracking of four failure mechanisms in a coating system; development of a laboratory management system capable of near real-time calculation of spectral ultraviolet (UV) dosage and spectral quantum yield; and instrumentation of four outdoor exposure sites with solar spectral radiometers to monitor quarter-hour changes in solar UV flux.

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Service Life of High Performance Structural Polymeric Composites

Dr. Joannie Chin, materials research engineer, and Dr. Jonathan Martin, leader, Organic Building Materials Group, submitted a patent application for a novel ultraviolet (UV) exposure chamber for artificially weathering materials such as coatings, plastics, textiles, and fiber-reinforced polymeric (FRP) composites to accelerate their response to UV radiation in combination with other weathering elements. The testing of such materials has been hampered by the non-reproducibility of exposure results between UV chambers. The non-reproducibility is due in part to spatial non-uniformities in the exposure conditions within and between chambers. A novel UV weathering device, based on integrating sphere technology, is being developed at BFRL. An integrating sphere consists of a spherical chamber with a highly reflecting inner surface that scatters incident radiation; that is, the integrating sphere behaves as a uniform UV radiation source. Test data indicate that the integrating sphere design also is capable of mitigating many of the spatial and temporal systematic errors encountered in other chamber designs. The elimination of such errors is expected to greatly aid the repeatability and reproducibility of artificial weathering results.

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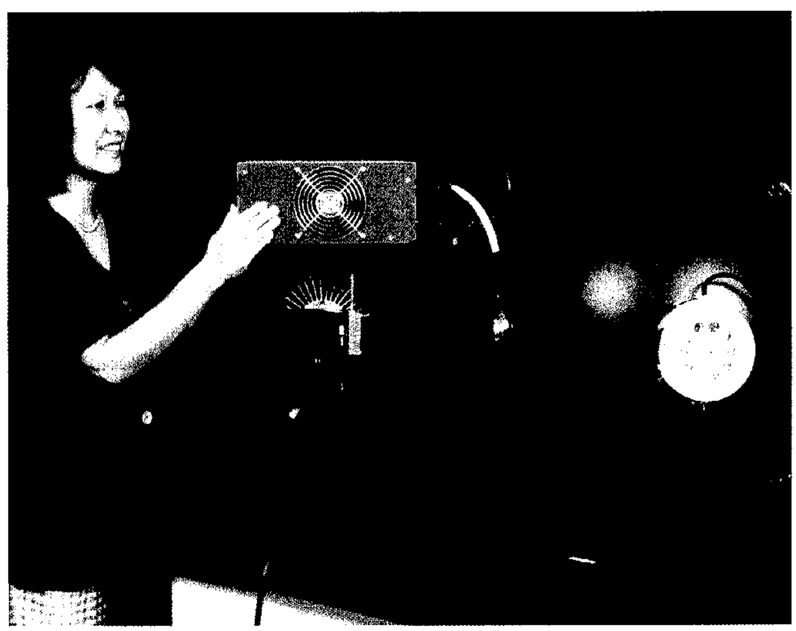
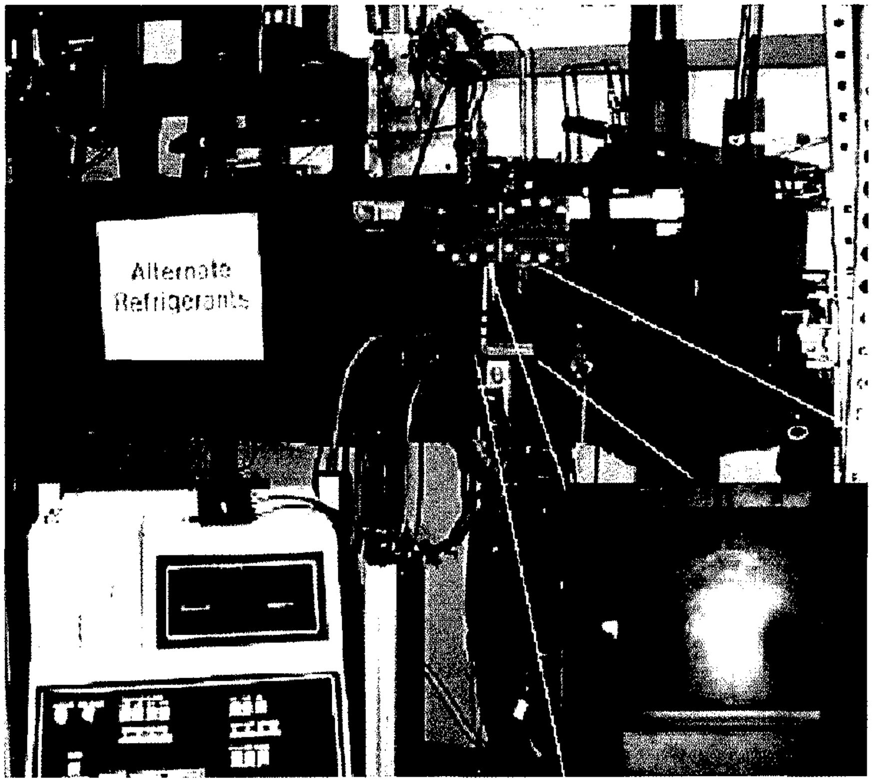


Dr. Joannie Chin, materials research engineer, is measuring the output intensity of a prototype photodegradation device capable of exposing polymeric materials to a high intensity, spatially uniform ultraviolet radiation flux. A commercially viable chamber is currently under construction.

VIII

Metrology for Sustainable Development

INTENDED OUTCOME. *Developed measurement and test methods, simulation models, and fundamental data that support the use, advancement, and life-cycle economy of sustainable design throughout the building industry. The specific focus of the research is on refrigeration and air-conditioning systems, thermal insulation, building integrated photovoltaic system, and indoor air quality.*



Pool boiling rig instrumented for a new BFRL fluorescence measurement technique.

A New Lubricant Concentration Measurement Technique for Pool Boiling

Dr. Mark Kedzierski, mechanical engineer, and Drs. Thomas Bruno and Matthew O'Neill from NIST's Chemical Science and Technology Laboratory demonstrated the feasibility of a new *in situ* technique for measuring the concentration of lubricant on a boiling heat transfer surface. The proposed technique relies on the fluorescence of the lubricant to determine the amount of lubricant that has accumulated on the heat transfer surface. The heat transfer performance of a boiling surface in refrigeration equipment is a strong function of the type of lubricant and its concentration in the refrigerant. After boiling the refrigerant, excess lubricant resides in a thin layer on the surface. Severe boiling performance degradation can occur in evaporators for high concentrations of lubricant on the surface. In measurements of 10 lubricant samples in special test equipment, the researchers found that lubricant concentration on an aluminum "stepped" target surface was a linear function of fluorescence intensity and the reflected harmonic from the surface. The next step of the research is testing the concept on an existing pool boiling rig using a bifurcated optical bundle with excitation and emissions detection in a single cable.

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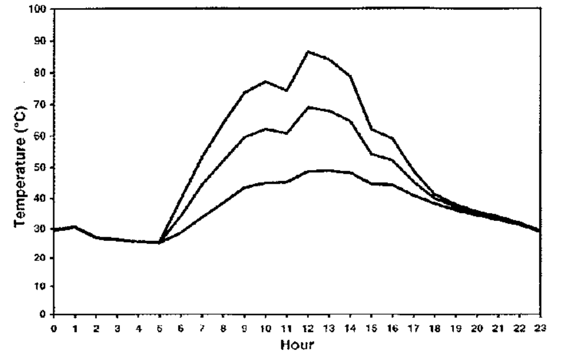
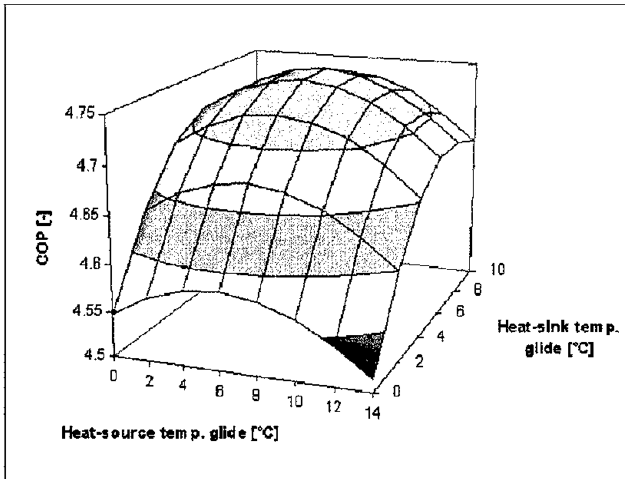
Potential Coefficient of Performance Improvement with R-407C

The use of zeotropic mixtures as CFC and HCFC substitutes has brought about a discussion of performance benefits due to matching of the temperature profile of the zeotrope with the temperature profile of the heat-source and heat-sink fluids. The matching of temperature profiles, also referred to as glide matching, results in smaller irreversibilities of the heat-transfer processes, which, in turn, results in an improved Coefficient of Performance (COP). The benefit of glide matching has been an elusive point in discussions of zeotropic mixtures because the COP improvement depend on operating conditions and heat exchanger design.

Mr. Marko Marques, guest researcher from Brazil, and Dr. Piotr Domanski, leader, Thermal Machinery Group, evaluated the potential benefit of glide matching for an alternative zeotropic mixture R-407C by simulating a system with a rigorous counter-flow, cross-flow, and parallel flow heat exchangers. The figure on page 22 presents the effect of glide matching on the COP in the cooling mode for a system with a cross-flow condenser and counter-flow evaporator for a constant-heat-flux simulation scenario. For a constant-heat-transfer-area scenario, the research showed that five percent COP improvement can be achieved using counter flow evaporators and condensers compared to a system with pure cross-flow heat exchangers. If parallel heat exchangers

Diurnal profile of roof temperature for residence in Phoenix, AZ during typical summer day. Reflectance values of roof: red = 0.1, green = 0.45, blue = 0.8.





COP for a system with a cross-flow condenser and counter-flow evaporator for different temperature glides.

are used, the COP penalty was approximately twice as severe as the benefit realized from counter flow glide matching (10 percent). Hence, optimization of refrigerant circuitry in a serpentine heat exchanger may be a crucial factor for obtaining high system efficiency.

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Reflective Roofs

Buildings in hot climates have long used light color construction such as whitewashing to minimize solar heat gains. In recent years, this design philosophy has received renewed attention in the United States, particularly in southern states with hot climates. Mr. Robert Zarr, research mechanical engineer, analyzed the effect of roof solar reflectance on the annual heating/cooling loads, peak heating/cooling loads, exterior roof temperatures, and economic cost analysis of residential buildings. The building loads were determined using BFRL's Thermal Analysis Research Program (TARP) for residential models in the following locations: Birmingham, Alabama; Bismarck, North Dakota; Miami, Florida; Phoenix, Arizona; Portland, Maine; and Washington, D.C. Models of the residential building were prepared based on architectural guidelines of a small one-story "ranch style" house and thermal performance requirements for the building envelope given in ASHRAE Standard 90.2-1993. These buildings were exposed to one year hourly weather data compiled by ASHRAE in the Weather Year for Energy Calculations. The analysis examined the effect of several factors including solar reflectance of the roof, ceiling thermal resistance, and attic ventilation, among others.

Results showed, for the above geographic locations, the effect of increasing the roof solar reflectance reduced annual and peak cooling loads was insignificant for peak heating loads, and detrimental (meaning increased requirements) for annual heating loads. The lowest annual cooling load was obtained at the highest level of roof solar reflectance and the greatest effect occurred for the case of an uninsulated attic. For higher levels of ceiling thermal resistance, the roof solar reflectance reduced the annual and peak cooling loads, but to a lesser extent. Increasing the roof solar reflectance was also found to decrease the exterior roof temperatures substantially (see photo). An economic cost analysis indicated that for Miami and Phoenix substantial annual cost savings were realized for the case of an uninsulated attic and for higher levels of ceiling thermal resistance, smaller annual cost savings also were evident. For Birmingham and, to a lesser extent Washington, D.C., annual cost savings were again realized for the case of an uninsulated attic for gas heating only. For Portland Maine and Bismarck, annual cost savings were generally small.

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Residential Mechanical Ventilation on Indoor Air Quality

Dr. Andrew Persily, leader, Indoor Air Quality Group, recently completed research, under a Cooperative Research and Development Agreement with the Electric Power Research Institute, to assess the impact of mechanical ventilation technologies on residential indoor air quality, ventilation, and energy consumption. Based on concerns about indoor air quality and trends toward tighter envelope construction, there has been increasing interest in mechanical ventilation in residential buildings. A variety of approaches were examined through field measurements and computer simulation studies. However, many of these efforts were limited in the aspects of performance considered. Dr. Persily's work focused on a fictitious two-story house in Spokane, Washington and employed BFRL's multizone airflow and contaminant dispersal model, CONTAM. The model of the house included a variety of factors related to airflow. Factors included exhaust fan and forced-air system operation, duct leakage and weather effects, and factors related to contaminant dispersal including adsorption/desorption of water vapor and volatile organic compounds, surface losses of particles and nitrogen dioxide, outdoor contaminant concentrations, and occupant activities. One-year simulations were performed for four different ventilation approaches: a base case of envelope infiltration only, passive inlet vents in combination with exhaust fan operation, an outdoor intake duct connected to the forced-air system return balanced by exhaust fan operation, and a continuously-operated exhaust fan.

The results of this work showed that envelope leakage, even in a relatively tight house, results in overventilation (relative to the residential ventilation requirement in ASHRAE Standard 62-1989) during severe weather. However, the same house can be underventilated during mild weather conditions. Incorporating a mechanical ventilation system increases the air change rate during mild weather, thereby reducing contaminant concentrations and occupant exposure. The mechanical ventilation approaches studied had reduced indoor pollutant levels from 40 percent to 20 percent; however, many resulted in a significant increase in energy consumption. In some cases, the energy consumption doubled relative to cases with no mechanical ventilation. The most substantial increases were shown in cases where forced-air fans were used to ventilate the building. The energy impacts can be reduced through a combination of tighter building envelopes, reductions in air distribution duct leakage, and the use of efficient fans in the ventilation systems.

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Low-Temperature Characterization of Thermal Insulation

Thermal insulation materials are used in many low-temperature applications for commercial and industrial buildings. Traditionally, BFRL has provided reference measurements and reference thermal insulation materials at moderate temperatures near ambient temperatures. As part of a two-year effort, Dr. Bora Rugaiganisa, guest researcher from Tanzania, has evaluated an apparatus for the measurement of thermal conductivity of thermal insulation materials from 110 K to 330 K at atmospheric pressure. The apparatus is a guarded-hot-plate conforming to ASTM Test Method C177 and can accommodate thermal insulation test specimens up to 200 mm in diameter and 40 mm in thickness. The guarded-hot-plate apparatus was evaluated using three glass-fiber reference materials and, whenever possible, by direct comparison with BFRL's one-meter guarded-hot-plate apparatus at temperatures near ambient conditions. The glass fiber reference materials were SRM 1450b Fibrous Glass Board, SRM 1451 Fibrous Glass Blanket, and CRM BCR 064 Resin-Bonded Glass Fibre Board from the Institute for Reference Materials and Measurements (IRMM) located in Belgium. Over the temperature range of 110 K to 330 K, the test data agreed with the certified values better than 2 percent. Further testing is in process to provide the necessary data to develop uncertainty statements in agreement with current NIST policy. The apparatus will be used to extend the low-temperature characterization of SRM 1450c Fibrous Glass Board down to 110 K.

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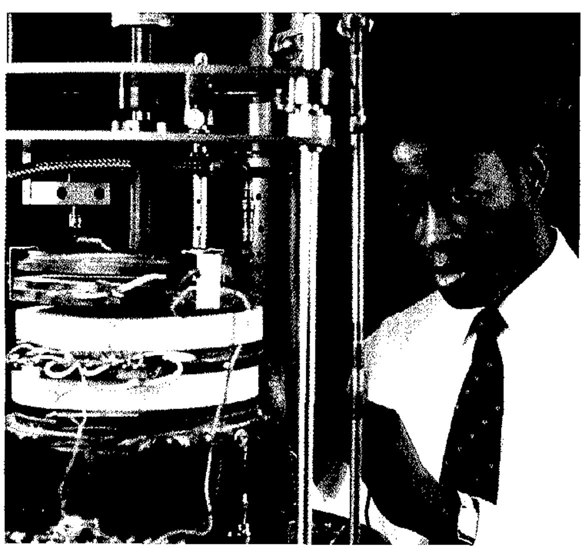
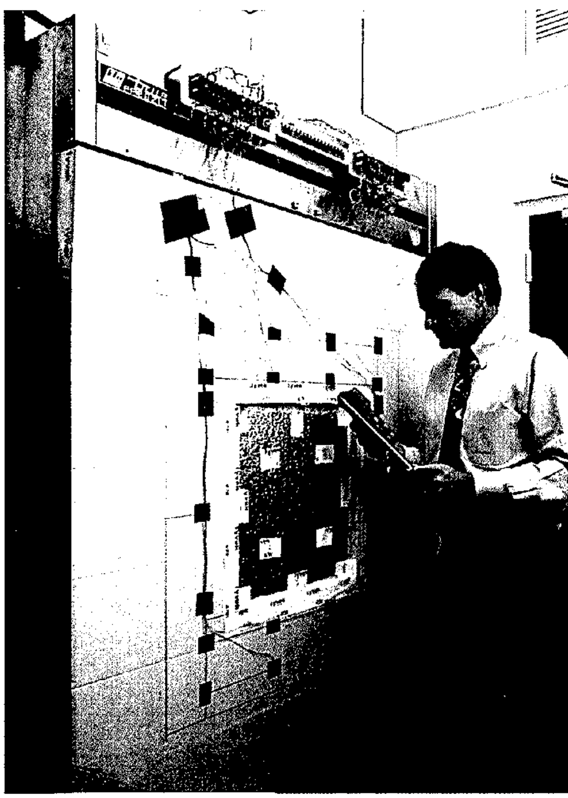


Dr. Rugaiganisa, guest researcher, evaluates low-temperature guarded-hot-plate apparatus.

Development of Super Insulation

Dr. Hunter Fanney, leader, Heat Transfer Group, and Division researchers completed measurements and analysis in a newly created advanced Insulation Testing Laboratory that enabled Dow Chemical to release the most efficient building insulation material on the market today, six times more efficient than glass fiber insulation. BFRL's new laboratory is equipped with a specially designed calorimeter capable of measuring the heat conducted through the panel as well as barrier materials that are required to guard against edge losses in super insulation. Dow's product consists of a patented, extremely small-cell porous foam material that can be evacuated and sealed within a metallized film. Through repeated measurements in the calorimeter, with infrared thermography, and use of thermal analysis software, Dr. Fanney and his research team were able to show Dow the effectiveness or lack thereof for candidate barrier designs and enable them to achieve their outstanding results. The product INSTILL™ is expected to be used first where space is a premium, as in the walls of refrigerators. The manufacturers can use thinner advanced panels to allow greater interior refrigerator-volume and yet still achieve the stringent energy efficiency standards on the horizon to combat global climate change. The U.S. Environmental Protection Agency estimated that $1 billion in annual energy savings would be realized if advanced insulation panels were incorporated into all refrigerators and freezers.



Dr. Fanney, leader, Heat Transfer Group, is operating the advanced insulation calorimeter to evaluate advanced insulation materials and gas-filled panels developed by industry and government laboratory partners.

In a letter to NIST's Director, Dow Chemical's R & D Director states, "The calorimeter within this laboratory is unique, in that it is capable of measuring the integrated thermal resistance of advanced insulation panels. While other measurements of obtaining an estimated integrated thermal efficiency based on multiple spot measurements exist, Dow is not aware of any facility within the United States that is capable of making these measurements with the degree of accuracy provided by NIST."

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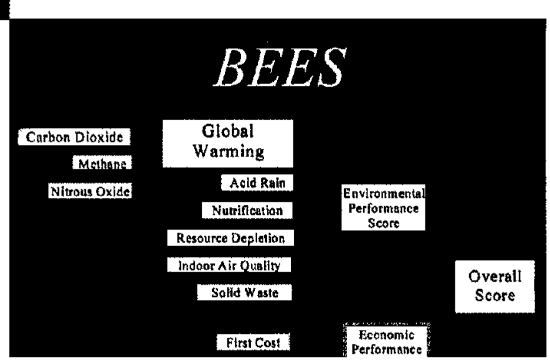
BEES

The BEES (Building for Environmental and Economic Sustainability) software implements a powerful technique for selecting cost-effective green building products. Developed by Ms. Barbara Lippiatt, economist, the tool is based on consensus standards and designed to be practical, flexible, and transparent. The Windows™-based decision support software, aimed at designers, builders, and product manufacturers, includes actual environmental and economic performance data for a number of building products. After

The BEES tool computes a building product's overall score based on life-cycle environmental and impact considerations.



incorporating comments received during a 1997 BETA test by over 125 reviewers worldwide, the first version of the tool, BEES 1.0, is now available. BEES measures the environmental performance of building products by using the environmental life-cycle assessment approach specified in the latest versions of ISO 14000 draft standards. All stages in the life of a product are analyzed: raw material acquisition, manufacture, transportation, installation, use, and recycling and waste management. Economic performance is measured using the ASTM standard life-cycle cost method, which covers the costs of initial investment, replacement, operation, maintenance and repair, and disposal. Environmental and economic performance are combined into an overall performance measure using the ASTM standard for Multi-Attribute Decision Analysis. For the entire BEES analysis, building products are defined and classified according to the ASTM standard classification for building elements known as UNIFORMAT II.

BEES 1.0, with environmental and economic performance data for 24 building products, is being distributed by the U.S. Green Building Council (www.usgbc.org). For more information on the tool, visit the BEES home page at www.bfrl.nist.gov/oae/bees.html, which includes a link to a BEES cover story published in the April 1998 issue of *The Construction Specifier.*

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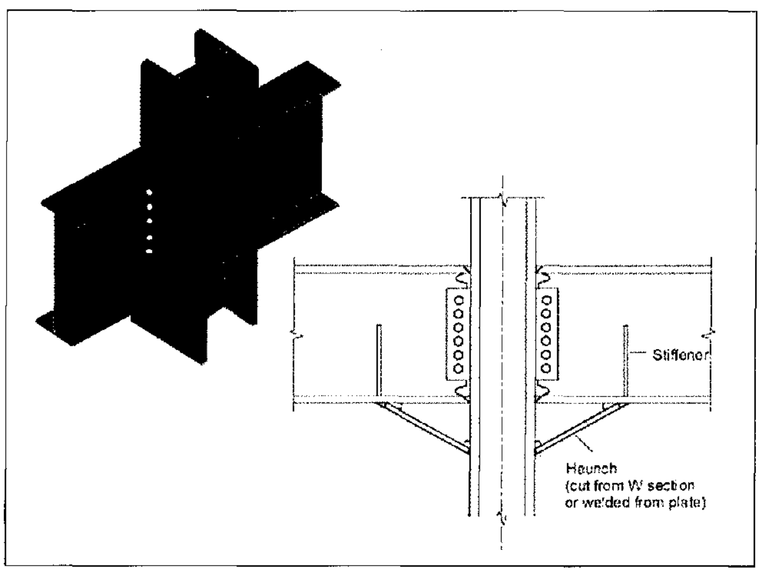
IX

Earthquake, Fire, and Wind Engineering

INTENDED OUTCOME. *Reduced economic losses from earthquakes, extreme winds, and post-disaster fires and increased public safety through the development and adoption of next-generation technologies and practices for disaster mitigation, response, and recovery. The BFRL products will be measurement, evaluation, and performance prediction technologies enabling cost-effective improvements in practice to increase the disaster-resistance of new and existing construction. The technologies encompass structural control for extreme loads, performance-based seismic design, next-generation standards for wind loads, enhanced fire control for post-disaster and urban wind-driven fires, non-destructive evaluation for condition assessment and quality control, high-performance disaster-resistant materials and systems, structural performance of housing systems, and the strengthening and rehabilitation of buildings and lifelines. In pursuing this objective, BFRL actively partners with the U.S. materials, architecture, engineering, and construction industries, government agencies (especially the Federal Emergency Management Agency and the National Oceanic and Atmospheric Administration), building standards and codes organizations (especially the Building Seismic Safety Council), and the fire services and disaster response communities.*

Seismic Rehabilitation of Welded Steel Frame Buildings

Dr. John Gross, leader, Structural Systems and Design Group, partnering with the American Institute of Steel Construction (AISC) and three leading U.S. universities, completed the first comprehensive guidance for the seismic rehabilitation of existing welded steel frame buildings. Conceived in response to the large number of beam-to-column connections that failed at the weldments during the 1994 Northridge, California,



Use of the promising connection modification concepts contained in the guidelines, to be published by AISC in its Design Guide series, will assure the safety of tens of thousands of similar buildings located in the U.S. and throughout the world.

earthquake, this project addresses a critical public safety problem. Use of the guidelines, which AISC is now ready to publish in its Design Guide series, will assure the safety of tens of thousands of similar buildings located in the United States and throughout the world. Rehabilitation of 50 percent of the existing steel frame buildings in "high" seismic regions of the United States alone is estimated to cost between $2 billion to $5 billion. The guidelines provide experimentally-validated response prediction models and design equations for three promising connection modification concepts that shift loading from the brittle weld joints into the beams, thus enabling the structure to absorb the earthquake's energy in a non-brittle manner.

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Structural Control for Extreme Loads

Recent earthquakes in the United States and Japan have resulted in casualties, significant economic losses, and disruptions in critical life-supporting facilities. One method to reduce losses from future disasters and to allow the structure to achieve target levels of performance is to use structural control systems, such as seismic isolation and passive energy dissipation devices. Structures designed with these devices throughout the world have shown that they can reduce structural responses to strong vibrations in a reliable and cost-effective manner. Although structural control devices must be tested before installation, national consensus standards for testing them do not yet exist.

Dr. Harry Shenton, formerly from BFRL, developed testing guidelines for base isolation devices in close cooperation with manufacturers, researchers, and practitioners. The guidelines are in the final stage of adoption as a national standard by the American Society of Civil Engineers (ASCE). Working with a similar expert panel, Dr. Michael Riley, research structural engineer, is nearing completion on developing similar testing guidelines for the relatively newer passive energy dissipation devices. It is expected these latter guidelines will be published as a consensus document and recommended to ASCE for adoption as a national standard.

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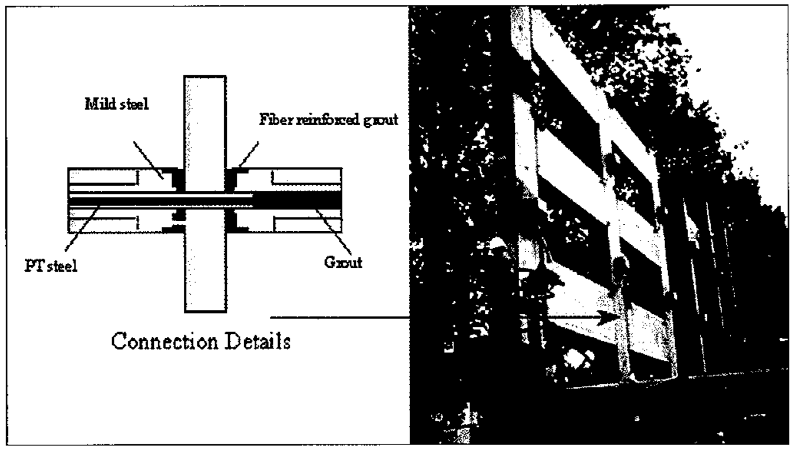

Innovative hybrid precast concrete connection system for high seismic regions was developed by the Structures Division in partnership with Pankow Builders and the American Concrete Institute.

Hybrid Precast Concrete Moment Frame System

An innovative hybrid precast concrete moment frame connection system for high seismic regions, developed by Ms. Geraldine Cheok, research structural engineer, and Dr. William Stone, leader, Construction Metrology and Automation Group, in partnership with Pankow Builders and the American Concrete Institute (ACI), received product approval from the International Conference of Building Officials (ICBO) Evaluation Service. In addition, the ACI (which issues the national standard for design and construction of concrete structures) Technology Transfer Committee has developed a provisional standard for the hybrid connection system. Industry has used the system in four construction projects — two buildings and two parking garages. The system is under consideration for the design of a more than 50-story concrete building in California. This research showed that the innovative precast concrete connection system performed as well as, and in some cases better than, monolithic concrete connections, thus making it possible to use precast construction in high seismic regions.

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Tornado Investigations

Following BFRL's field surveys and evaluation of structural damage caused by the May 1997 tornado in Jarrell, Texas, Dr. Long Phan, research structural engineer, and Dr. Emil Simiu, NIST Fellow, published *The Fujita Tornado Intensity Scale: A Critique Based on Observations of Jarrell Tornado of May 22, 1997,* NIST Technical Note 1426, 1998, to document damage observations and provide estimates of the credible range of wind speeds. Using structural engineering considerations, Drs. Phan and Simiu concluded that the damage caused by the Jarrell tornado can be explained by wind speeds corresponding to an F3 rating (i.e., 71 m/s to 92 m/s) on the Fujita tornado intensity scale, which includes six tornado categories, from F0 to F5. The F5 rating (117 m/s to 142 m/s), officially issued by the National Weather Service (NWS) and widely reported by the media, need not be assumed to explain the observed damage. The investigators ascribed the misclassification of the tornado rating to: 1) possible misinterpretation by non-engineers of ambiguous terms used in the Fujita scale, such as well-constructed houses and strong frame houses and to 2) failure of the Fujita scale to account explicitly for the dependence of structural damage upon the design wind speed specified and enforced for the geographical location of interest (for example, damage that could be attributed to an F5 tornado in a zone with the specified design wind speed of 63 m/s could be explained by an F3 tornado in a 40 m/s design wind speed zone). These conclusions are significant because ascribing failures to unrealistically high wind speeds undermines the application and enforcement of design standards that can reduce loss of life and property caused by most tornadoes. An article based on the Technical Note, "Tornado Aftermath: Questioning the Tools," was published in the December 1998 issue of ASCE's magazine, *Civil Engineering.*

Also in 1998, staff from the Structures Division conducted similar aerial and ground surveys of structural damage caused by tornado outbreaks in Central Florida (February 1998) (F4 rating assigned to the most severe outbreak), in Central Alabama (April 1998) (F5 rating), and in Spencer, South Dakota (June 1998) (F4 rating). A report summarizing the findings of these three field investigations was published in early 1999.

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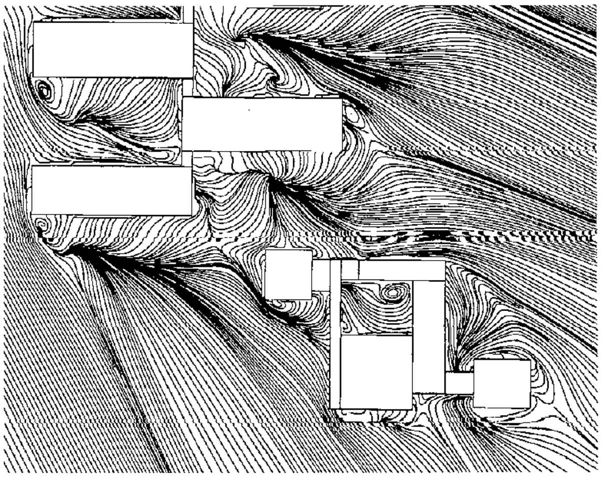
Computational Wind Engineering

Billions of dollars and a substantial numbers of lives are lost each year due to damage and destruction from wind loading. A predictive capability to guide the effective design, construction and retrofitting of the built environment to reduce these hazards is needed. In particular there is a needed capability to determine pressure fluctuations induced by local meteorology and neighboring structures on a target. Computational wind engineering (CWE) is a newly developing area of research which has the potential to reduce or replace expensive wind-tunnel measurements needed for design by building engineers. It is becoming practical now because of the revolutionary advances in computers and communications. The potential for developing computerized databases describing the built environment along with databases currently available for atmospheric winds can provide the data for computational exploration of wind effects on structures.

Collapsed, Oakgrove Elementary and High School Building constructed of lightly reinforced masonry block and brick veneer walls with RC bond beams that connected the steel roof truss to walls, Jefferson County, Alabama.



Ground level average wind over a portion of the NIST campus.

Drs. Ronald Rehm and Emil Simiu, NIST Fellows, are leading BFRL's CWE research to study wind effects on structures in site-specific locations. They have calculated wind pressures on a target building knowing the local meteorology and the structures in the neighborhood of the building. The figure above shows an example of this new capability. It is a unique computation of wind flow over a portion of the NIST, Gaithersburg, Maryland campus. The computation has extremely high resolution, using more than four million grid cells, and is larger than any other CWE computation published. The figure shows the average wind field near the ground level looking from above. The wind is flowing from the northwest over the NIST Administration Building (lower right of picture) toward the complex of four buildings. Findings from this CWE research will serve as the bases for developing simulation models for use by designers during the early design phase to understand the site-specific analysis of the response of their proposed building to high winds and its effect on neighboring buildings.

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Fire Whirl Simulation

Fire whirls are a rare but potentially catastrophic form of fire. For one to exist, there must be an external source of organized angular momentum that produces large swirl velocity components as air is entrained into the fire plume. The vertical acceleration induced by the buoyancy generates strain fields that stretch out the flames as they wrap around the nominal plume centerline. Fire whirls are known to increase substantially the danger of naturally occurring or post-disaster fires.

Dr. Francine Battaglia, mechanical engineer and National Research Council postdoctoral research associate, is performing a numerical investigation of swirling fire plumes to understand how swirl alters the plume dynamics and combustion. Large eddy simulation (LES) numerical results show that the structure of the fire plume is altered significantly when swirl is imparted to the ambient fluid. LES calculations indicate that the whirling fire constricts radially and stretches the plume vertically which, in turn, reduces the entrainment of ambient fluid. The swirling plume increases the combustion rate and the intensity of the velocities generated by the fire. It also can loft more and larger fire brands, thereby increasing significantly the potential for disaster. The figure is an instantaneous view of a whirling fire plume where the three major zones are identified. The blue ribbon is a sample Lagrangian trajectory of the flowfield. From this perspective, a fluid element in the swirling flow is observed to wrap around azimuthally and identifies where the plume stretches vertically.

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Simulations of a fire plume showing three major zones: the continuous flame (red), the intermittent region (yellow), and the plume region (gray).

X

Advanced Fire Measurements and Fire Fighting Technologies

INTENDED OUTCOME. *New capability for corporate or commercial testing laboratories for measuring a product's fire behavior in the laboratory and in the field; improvement in fire fighter safety and effectiveness through new measurements, test methods, predictions, and fire ground information technology. The BFRL products will be improved measurement methods for the performance of products and fire control technologies and real-time measurement and predictive tools for command and control of emergencies. In pursuing this objective, BFRL actively partners with the U.S. Fire Administration and the National Institute for Occupational Safety and Health for fire fighter safety; also BFRL cooperates with the Montgomery County Fire Department, New York City Fire Department, and the Austin Texas Fire Department.*

Conducting tire fire suppression experiments to determine the effectiveness of environmentally friendly fire extinguishing agents.

Performance of Fire Fighting Agent

Mr. Daniel Madrzykowski, leader, Large Fire Research Group and Mr. David Stroup, fire protection engineer, under sponsorship of the United States Fire Administration, completed a series of experiments to demonstrate the suppression effectiveness of water-based fire fighting agents. Accepted test procedures for suppression effectiveness do not exist. The results of these experiments are a first step toward establishing standardized tests for evaluating the fire fighting effectiveness of water-based agents.

Working with the Maryland Fire and Rescue Institute, the U.S. Navy, the U.S. Forest Service, and the Underwriters' Laboratories, Messrs. Madrzykowski and Stroup have demonstrated test methods that provide a basis for clear differentiation of fire fighting effectiveness between water and fire-fighting agents. The test methods developed characterize the agent's capability to provide surface cooling and fuel penetration, water retention on surfaces, ignition inhibition, tire fire suppression, and Class B fire suppression.

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Protecting Fire Fighters

For more than 20 years the protective clothing worn by firefighters has improved dramatically, giving the firefighter greater protection from fire, heat, and moisture. Yet, firefighters continue to suffer burns at a stubbornly constant rate. With support from the U.S. Fire Administration and the National Institute of Occupational Health, Mr. James Randall Lawson, physical scientist, and Division researchers are examining the thermal environment of firefighters' protective clothing under stage and attack conditions of structural firefighting. Mr. Lawson is developing the measurement tools and techniques needed to determine the performance of firefighters' protective clothing. He has examined the broad range of fire conditions and events that lead to burn injuries.

Firefighters avoid contact with the flaming envelope, that area bounded by the flame's edge. Many firefighter burn injuries are not caused by flame contact, but by factors such as contact with hot surfaces, excessive exposure to high thermal radiation and/or insufficient protection provided by protective clothing. Moisture from perspiration or fire hose wetting cause significant changes in protective clothing's thermal performance. These changes often led to serious burn injuries cause by hot vapors or steam. Mr. Lawson developed detailed recommendations for improving protective clothing

Mr. David Stroup, fire protection engineer, aligns a laser light extinction smoke meter, the first of its kind to measure the mass concentration of smoke, before conducting a fire test in BFRL's Large Fire Research Facility Furniture Calorimeter.

Improved measurement tools and techniques from this research will significantly reduce firefighter injuries as shown by the damaged fire fighter gear.

including reducing and controlling the moisture inside the clothing. Details on these studies are in NIST's reports: *Fire Fighter Protective Clothing and Thermal Environments of Structural Fire Fighting,* NISTIR 5804, and in *Firefighter Thermal Exposure Workshop: Protective Clothing, Tactics, and Fire Service PPE Training Procedures,* SP911. The reports specifically recommend the need to inform and train firefighters about the performance limits of their clothing and strongly urges that firefighter training and tactics avoid placing firefighters in an environment where the limit of the protective clothing is challenged.

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Where there's smoke, . . .

All fires produce smoke, and that smoke can be beneficial (when it triggers a smoke detector) or harmful (when it impedes escape). Therefore, it is critical to know how much smoke a burning object produces and where that smoke is moving relative to people or fire sensors. Dr. George Mulholland, research chemist, produced a breakthrough in quantifying smoke during the early stages of a fire when the air supply is plentiful. Dr. Mulholland and his co-workers performed experiments on chemically different fuels in various types of laboratory burners, determining the mass specific extinction coefficient of the smoke in each case. He also performed a critical evaluation of prior data developed at BFRL and elsewhere on fires of different scales. His analysis shows that the data coalesce about a value of 8.5 ± 2.0 m^2/g with only a modest dependence on fire size, fuel, and flame conditions. This finding enables the use of light extinction measurement methods for measuring the mass production rate of soot from a mixed fuel such as an upholstered chair or composite furniture. This new light extinction method will obviate the more cumbersome mass extraction methods and offer the potential for both time- and space-resolved determinations.

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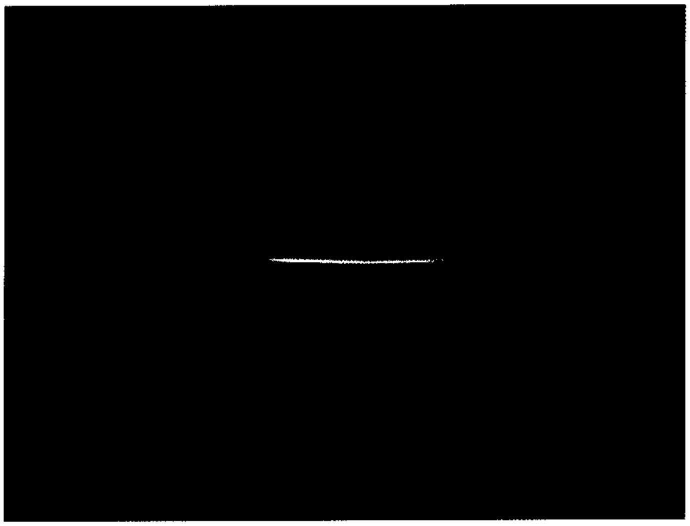
New Fire Suppression Technology for Aircraft

Fuel spray fires in engine nacelles are of concern to military and commercial aviation. The current suppressant of choice is halon 1301, CF_3Br, a chemical that is out of production due to its deleterious effect on stratospheric ozone. Dr. Anthony Hamins, mechanical engineer; Mr. Thomas Cleary, chemical engineer; and Dr. Jiann Yang, research mechanical engineer, have worked with engineers at Wright Patterson Air Force Base (WPAFB) to test several approaches to suppressing these fires, with and without a fuel re-ignition source. The test includes two generic types of solid propellant gas generators (SPGG), similar to those used to inflate automobile air bags. One type produces inert gases only, the other inert gases plus potassium carbonate powder, an efficient fire suppressant. Early versions of this type of device are already being installed on pre-production military aircraft. While demonstrating some effectiveness, they also have presented problems that need to be overcome with a next-generation design. Well-instrumented tests in the WPAFB engine nacelle simulator have produced insight into the mechanisms by which SPGGs suppress the flames. These researchers have developed a simple model of the SPGG delivery. Assuming plug flow of the SPGG effluent, average agent concentrations are calculated as a function of time in the nacelle. The agreement with the experimental measurements is reasonable. Under the DoD Next-Generation Fire Suppression



Counterflow diffusion flame of methane seeded with an iron precursor. The two-zone structure shows the formation region of the inhibiting iron intermediates to be separate from the main reaction zone.

Program, Fire Science Division researchers will develop a screening test for suppression delivery methods like SPGGs.

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Mechanism of Super Flame Suppressant

With the cessation of production of the halon fire suppressants, there is a search for equally effective alternatives. One approach being pursued by BFRL scientists is to understand the mechanisms of highly efficient chemicals, even if they are not usable for other reasons. They would then look for other chemicals that possess the desirable features without the undesirable attributes.

Iron pentacarbonyl is one of those chemicals. Its inhibition efficiency is very high up to a point, but then falls off sharply. It also is highly toxic. Dr. Gregory Linteris, mechanical engineer, and Dr. Marc Rumminger, National Research Council's postdoctoral research associate, along with Dr. Valeri Babushok, a guest worker from Russia, and Dr. Dirk Reinelt, a recent visiting scientist from BASF, Germany, have examined this compound added to laboratory flames. They have constructed a gas-phase inhibition mechanism involving catalytic removal of hydrogen atoms by iron-containing species. At low additive levels, the model predictions and experimental data compare well, indicating that the flame is mainly slowed by homogeneous, gas-phase chemistry. However, the model does not sufficiently account for the falloff. The team suggests this drop in efficiency is due to condensation of the active species Fe and FeO, which are calculated to be supersaturated in some regions of the flame. The results have been published in *Combustion and Flame.*

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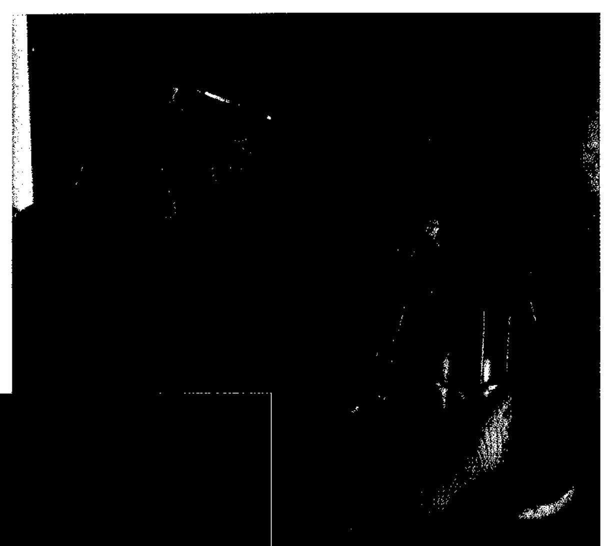
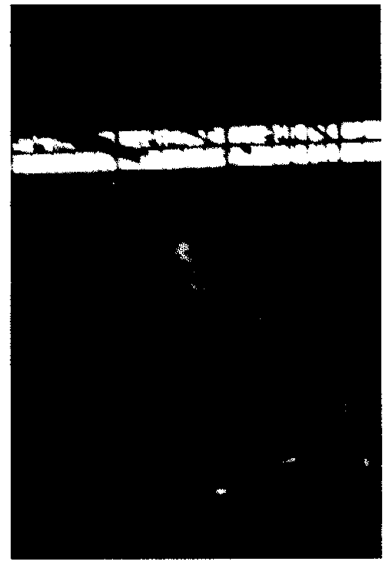
Improved Method for Determining Flammability of Alternative Refrigerants

Dr. William Grosshandler, leader, Fire Sensing and Extinguishment Group, and co-workers have developed a new method for identifying the flammability of refrigerants that are being considered as substitutes to non-flammable, but ozone depleting CFCs. The current approach used by industry for assigning the flammable limits, ASTM E681, requires the subjective judgment of the test operator on whether or not a flame emanating from a spark spreads beyond a certain dimension within a closed vessel. Operator variability and a sensitivity of the results to the ignition process, mixture humidity, and temperature are of concern to the

Dr. Carole Womeldorf, mechanical engineer, is part of a research team finding ways to better measure the flammability of alternative refrigerants. The work, sponsored by the Air-conditioning and Refrigeration Technology Institute and the Department of Energy, bases the limits of flammability on conditions which cause the flame, shown in the Insert, to extinguish, which is a much more conclusive event than is observed in the current ASTM method.



An example of one of the fires conducted in a 15 m high hanger to test the activation of fire detectors.



Air-conditioning and Refrigeration Institute, and the Department of Energy, which are supporting BFRL research to better understand the spread of flame through refrigerant air mixtures and to demonstrate an alternative means to measure flammability not subject to the same deficiencies. By decreasing the fuel/air ratio of an established premixed, counter-flow flame (while maintaining the flow velocity constant), an unambiguous extinction point can be determined. The extinction concentration of refrigerant can be measured for decreasing flow velocities, so that the concentration at zero flow can be determined by extrapolation. Using this method, a distinct flammability limit can be determined even for weak fuels like many of the hydrofluorocarbons under consideration for CFC refrigerant replacements. The theory of operation and a description of the experimental facility designed specifically for the new generation of refrigerants are included in the final report to the Air-conditioning and Refrigerating Technology Institute. It also was published by NIST as *Flammability Limit as a Fundamental Refrigerant Property*, NISTIR 6229. The results for various refrigerant mixtures are compared to data taken in the ASTM E681 apparatus, the uncertainties of the measurements are quantified, and recommendations are made for further activities that can lead to a science-based methodology for assessing the risk of fire from refrigeration machine working fluids.

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Detector Response in High Bay Spaces

Current guidelines for designing fire protection systems for aircraft hangars were developed with the primary objective of saving the building, and with less consideration given to minimizing damage to the hangar's contents. The high cost of modern aircraft justifies reexamining present fire detection and sprinkler activation methods to determine if new approaches could lead to a quicker response to a smaller fire, with the benefit of substantially reduced damage to aircraft adjacent to the fire source. The Fire Safety Engineering Division created a partnership with the Naval Facilities Engineering Command and representatives from the detector industry to investigate fire detection in these spaces.

Ms. Kathy Notarianni, research fire protection engineer, lead a series of experiments in two Navy high bay aircraft hangars with the purpose to test the response of the latest generation of fire detectors and sprinkler heads using a wide range of fire sizes. Over 200 instruments, sprinklers and detectors were used in each full scale experiment to measure the behavior of heat and smoke in high bay areas and their effect on the response time of fire detection and sprinkler systems. Included in the tests were the effects of draft curtains, flat versus curved ceilings, and wind blowing through hangar doors on detector activation.

When the experimental results were compared with zone fire model predictions, it was found that the zone fire models generally under predicted the plume centerline temperature and ceiling jet temperature when a hot layer was present. A new ceiling jet correlation was developed which included the impact of a hot smoke layer on the radial dependence of the temperature as measured from the plume centerline. The importance of a fire size dependent radiative fraction was demonstrated as it was shown that the plume centerline temperature could be predicted using an algorithm developed by Dr. David Evans, chief, Fire Safety Engineering Division, when this effect was included in the calculation.

A new zone fire model, JET, was developed Dr. William Davis, physicist, which predicts plume centerline temperature, ceiling jet temperature, and sprinkler activation in high ceiling situations using the ceiling jet correlation and plume algorithm as is described above. The computer model JET and the detector activation studies conducted in the navy aircraft hangars provide the tools necessary to perform prediction based design for detector activation in high ceiling structures.

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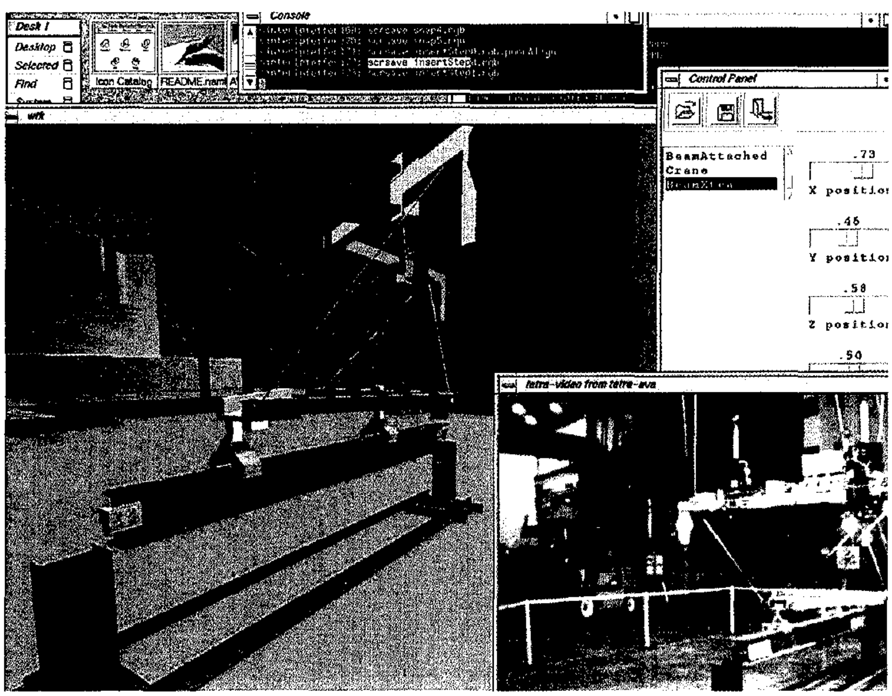
Construction & Building

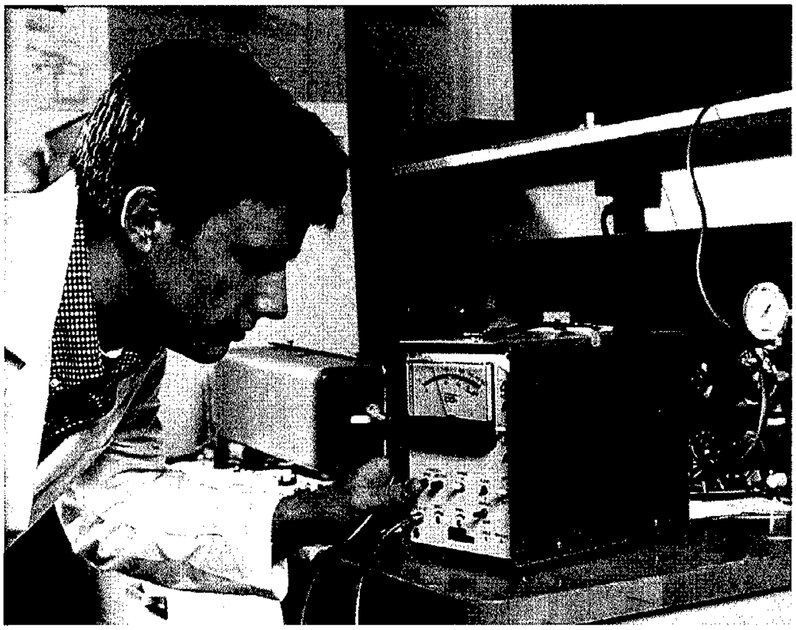
The activities of the National Science and Technology Council (NSTC) Subcommittee on Construction and Building (C&B) have profound effects on the BFRL program. BFRL co-chairs the C&B and maintains its secretariat. NSTC, a cabinet-level group charged with setting federal technology policy, coordinates R&D strategies across a broad cross-section of public and private interests. C&B defines priorities for federal research, development, and deployment related to the industries that produce, operate, and maintain constructed facilities, including buildings and infrastructure. These priorities, and related collaborations with industry and government, guide the focus of the Laboratory's programs.

The C&B Program focuses on making technologies and practices capable of achieving the following goals and available for general use in the construction industry by 2003. The goals, based on 1994 business practices and endorsed by industry leaders, are:

- 50 percent reduction in delivery time from the decision to construct a new facility to its readiness for service;
- 50 percent reduction in operation, maintenance and energy costs. Operation and maintenance costs over the life of the facility usually exceed its first cost and may do so on an annualized cost basis. Energy, water, sewage, waste, communications, taxes, insurance, fire safety, plant services, etc., represent costs to society in terms of resource consumption;
- 30 percent increase in productivity and comfort. The annual salary costs of the occupants of a commercial or institutional building are of the same order of magnitude as the capital cost of the building. Improvement of the productivity of the occupants is the most important performance characteristic for most constructed facilities;
- 50 percent fewer occupant related illnesses and injuries. Examples are avoidable injuries caused by fire or natural hazards, slips and falls, legionnaires' disease from airborne bacteria, often associated with a workplace environment (sick building syndrome) and building damage or collapse from fire, earthquakes, or extreme winds;
- 50 percent less waste and pollution at every step of the delivery process, from raw material extraction to final demolition and recycling of the shelter and its contents;



BFRL's computer automated construction testbed is positioning an "I" beam onto a frame. Findings from pilot projects such as this one will contribute to the National Construction Goal of a 50 percent reduction in delivery time of constructed facilities.



Mr. Kevin Denton, coop student at the University of Maryland, prepares a carbon dioxide monitor for field measurements of indoor air quality in an office building as part of meeting the C&B program goal of achieving a 50 percent reduction in occupant related illnesses and injuries.

- 50 percent more durability and flexibility. Durability denotes the capability of the constructed facility to continue (given appropriate maintenance) its initial performance over the intended service life, and flexibility denotes the capability to adapt the constructed facility to changes in use or users' needs;
- 50 percent reduction in construction work illnesses and injuries. Although the construction workforce represents about six percent of the nation's workforce, it is estimated that the construction industry pays for about one-third of the nation's workers' compensation. Construction workers die as a result of work-related trauma at a rate that is 2-1/2 times the annual rate for workers in all other industry sectors.

C&B activities in 1998

Formation of the Partnership for Advancing Technology in Housing (PATH)

In response to national needs and interests of the housing sector, C&B organized the Partnership for Advancing Technologies in Housing (PATH), which became a Presidential initiative announced in 1998. PATH brings together government and industry to develop, demonstrate, and deploy housing technologies, designs, and practices that can significantly improve the quality, durability, energy efficiency, environmental performance, and affordability of new and existing houses. The Department of Housing and Urban Development is leading the PATH program. The government's primary role in the partnership is to act as catalyst and facilitator, to coordinate and promote individual agency programs that contribute to PATH goals, and to help remove unnecessary regulatory barriers to innovation. Private industry will develop and deploy the technologies for the next generation of American housing.

The PATH's Web site describes many innovative technologies that have less than 5 percent market share, that contribute to the PATH goals, and that have product(s) available today. The site also describes some "best practices" used in home construction. The site will include a section for builders comments, an on-line question and answer forum, and an educational section on how to help assess installation quality. The PATH Web site is www.path-net.org. BFRL's objective, Performance Standards System for Housing, represents NIST's programmatic response to the PATH initiative.

Partnership for Advancing Infrastructure and its Renewal

The Partnership for the Advancement of Infrastructure and its Renewal (PAIR) is being developed as a partnership of existing and future government, private sector, and academic programs to develop the innovative technologies needed to revitalize and advance the nation's physical infrastructure. "Infrastructure" comprises transportation, energy, telecommunications, water supply and sewerage, and key public institutional resources such as schools, hospitals, and prisons.

In April 1998, C&B, the Department of Transportation, and Civil Engineering Research Foundation organized a workshop for national transportation leaders to address the critical need for innovation for renewal of the transportation infrastructure. A second workshop was convened in June 1998, to focus on innovations for telecommunications, energy infrastructure, and water supply and sewage. At both workshops participants concurred that PAIR is a key element in the accelerated use of innovation, particularly advanced materials and processes in new construction, repair, retrofit, and maintenance of the physical infrastructure. BFRL's Building Materials Division will provide technical support to help PAIR achieve its mission.

Streamlining Regulation

With major support from the federal agencies of the C&B Subcommittee and the National Conference of States on Building Codes and Standards (NCSBCS), C&B has organized a program Streamlining the Nation's Building Regulatory Process to develop and gain the adoption of a package of model reforms which when adopted by federal, state, regional or local governments will enhance public safety, economic development, and environmental quality while reducing by as much as 60 percent the amount of regulatory processing time it takes to move projects from the initial step of zoning approval through to the last step of issuance of the certificate of occupancy.

In January 1997 NCSBCS issued a national call for the public and private sector to submit case studies of existing streamlined processes and procedures which reduce regulatory overlap. Currently more than 100 case studies have been received. Executive summaries of most of those case studies are now available on the NCSBCS Web site at www.ncsbcs.org/.

Working with Industries of Construction

C&B participates in and supports the CONstruction MATerials (CONMAT) Council, which consists of 12 different material groups (aluminum, coatings, concrete, fiber-reinforced composites, geo-synthetics, masonry, plastics, roofing materials, smart materials, stainless materials, steel, and wood) and liaison members from public and private agencies. These groups joined forces in a $250 million effort to plan and implement a national program of research development and deployment.

C&B is working with the American Society of Mechanical Engineers to develop a joint government/industry program for mechanical and electrical systems industries similar to CONMAT. This program will involve organizations representing heating and air-conditioning systems, security systems, fire alarm systems, electrical systems, and elevators and escalators.

C&B is supporting a National Academy of Sciences study to document the relationships between the workplace environment and worker productivity.

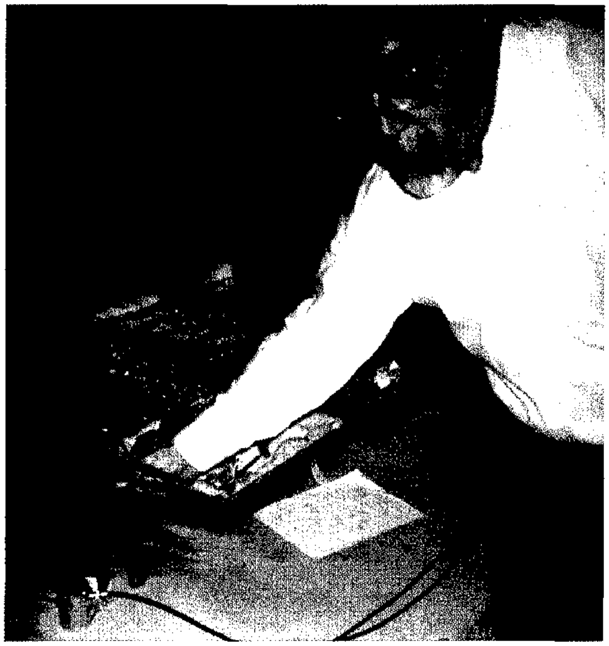
The Laboratory places great emphasis on effective outreach with its customers. During 1998, outreach included staff participation in over 130 national and international standardization activities and providing leadership in standardization organizations.

These activities included chairing more than 20 voluntary standardization activities; partnering with industry in 52 Cooperative Research and Development Agreements; publishing more than 260 reports and articles for research, professional, and trade journals and computer model software packages; making presentations at hundreds of scientific, building, and fire safety community organizations; hosting more than 1,700 visitors to its facilities; responding to more than 19,000 requests for information; conducting symposia in cooperation with other organizations concerned with building research and practice; hosting the biweekly Fire Research Seminars for NIST staff and colleagues from the fire community; maintaining and expanding the Fire Research Information Service (FRIS) consisting of national and international fire research literature and FIREDOC, the automated database of fire research literature (FRIS is the only comprehensive national library resource for the fire community;) and enhancing BFRL's Web site found at www.bfrl.nist.gov.

Codes and Standards

Through active participation and leadership in many Standards Development Organizations (SDOs), BFRL staff contribute significant time and technical expertise to the process of developing national and international standards. For example, BFRL staff serve, on behalf of the American National Standards Institute (ANSI), as the U.S. participant on the International Organization for Standardization (ISO), Technical Management Board's Technical Advisory Group 8 - Building. In addition, BFRL staff work within specific organizations including the American Concrete Institute (ACI), American Society of Civil Engineers (ASCE), American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), American Institute of Steel Construction (AISC), National Fire Protection Association (NFPA), American Society for Testing and Materials (ASTM), and the International Organization for Standardization (ISO). In ASTM alone BFRL is active on Committee C01, on Cement; Committee C09 on Concrete and Concrete Aggregates; Committee D01, on Paint and Related Coating Materials; Committee D04, on Road and Paving Materials; Committee D08, on Roofing, Waterproofing and Bituminous Materials; Committee D20, on Plastics; Committee E05, on Fire Standards; Committee E06, on Performance of Building Constructions; Committee E12, on Appearance of Materials; and Committee G03, on Durability of Nonmetallic Materials. BFRL serves on

Mr. Michael Smith, physical science/engineering technician, is operating the Cone Calorimeter, a BFRL-developed device that has become ASTM and ISO standard test methods for determining the small-scale rate of heat and smoke release by burning materials.



Dr. Nicholas Carino, co-developer of the impact-echo device, is shown using an early prototype of the device.

the National Manufactured Home Advisory Council, which provides technical advisory services about the preemptive federal code for manufactured housing. BFRL is a member of the ANSI Construction Standards Board and, through its involvement with ANSI, BFRL is supporting the development of a strong U.S. position in regional and international standards activities. Working in accordance with a Memorandum of Understanding between NIST and the International Code Council (ICC), BFRL is supporting the efforts to create a single set of national model building codes and is a member of the ICC's Industry Advisory Committee.

ASTM Standard on the Impact-Echo Method

In 1998, ASTM adopted the first standard in the world on using the impact-echo method for non-destructive measurement of the thickness of concrete members. This research that forms the basis for the method was performed by Dr. Nicholas Carino, leader, Structural Evaluation and Standards Group, in cooperation with Professor Mary Sansalone at Cornell University. In 1997, Dr. Carino and Professor Sansalone developed a draft standard and championed its adoption by ASTM Committee C09 on Concrete and Concrete Aggregates. The standard is expected to have a major impact on the highway industry, where measurement of pavement thickness is a critical aspect of quality control and payment schedules. Until now, these measurements have been made by drilling cores, a process that is time-consuming, expensive, destructive, and limited in coverage. The impact-echo method will allow more pavement to be assessed at reduced cost.

ASTM Standard on Interpretation of Indoor Carbon Dioxide Concentrations

Dr. Andrew Persily, leader, Indoor Air Quality Group, played a key role in the development and approval of a new ASTM standard guide on the interpretation of indoor carbon dioxide concentrations. The standard, D6245 Guide for Using Indoor Carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation, was approved by ASTM Committee D22 on Sampling and Analysis of Atmospheres. The guide describes how indoor carbon dioxide concentrations can be used to determine ventilation performance in buildings and to assess certain aspects of indoor air quality. In recent years, there have been numerous circumstances in which indoor carbon dioxide concentrations have been misinterpreted in evaluations of indoor air quality and ventilation. In response to that confusion, Dr. Persily and his colleagues conducted an extensive experimental program to evaluate the circumstances in which these evaluations could be performed reliably and those in which they could not. For example, the work showed that spot measurements could be related to outdoor air ventilation rates per person only under situations in which the ventilation rate and building occupancy were constant and the indoor carbon dioxide concentration had achieved steady-state. Up to that point, these requirements had not been fully appreciated by users in the field. The existence of this standard guide provides the information needed on how to interpret indoor carbon dioxide concentrations properly and will greatly reduce the misuse of this potentially useful approach in the future.

Revision of ASTM E5 Standard on Measuring Fire Smoke Toxicity

Dr. Richard Gann, chief, Fire Science Division, was instrumental in effecting key revisions to the recently developed Standard Test Method for Measuring Smoke Toxicity for Use in Fire Hazard Analysis (E1678). Based on the research of a BFRL project led by

Dr. William Pitts, research chemist, the Standard was amended to reflect the large amount of carbon monoxide (CO) produced in postflashover fires, where the combustion is severely underventilated. This high CO yield is independent of the nature of the combustibles in the room and dominates the lethality of the smoke produced. A second upgrade of the Standard was the inclusion of the accuracy of the method in predicting the lethality of smoke from real-scale room fire tests. The combination of these changes will enable fire hazard analyses to show that the lethality of the smoke that causes most fire deaths is not fuel-specific, reducing the likely levels of fire regulation and product liability.

Revision of NFPA 2001

Dr. William Grosshandler, leader, Fire Sensing and Extinguishment Group, chairs a task group of the NFPA 2001 Standard on Clean Fire Extinguishing Systems which is looking into problems that result from electrical equipment that cannot be de-energized prior to applying a fire suppressant. Working on a CRADA with 3M, Dr. Grosshandler and his research team are quantifying the additional amount of clean agent that must be applied when substantial sources of electrical heating may be present. The NFPA Standard is currently being revised based upon some of the information developed by the task group.

Collaboration With Industry

1998 Cooperative Research and Development Agreement

BFRL frequently works with other organizations to share costs and resources in solving problems whose solutions often have industry-wide application. Through Cooperative Research and Development Agreements (CRADAs), industry partners can be granted proprietary rights to intellectual property resulting from the collaboration. During 1998, BFRL partnered with 49 U.S. companies and academia in 52 cooperative R&D projects.

Industry Consortia

BFRL encourages and supports the formation of consortia by firms and organizations to solve industry problems. Industry, academia, and other organizations interested in implementing research findings can work with BFRL in developing technologies in a cooperative environment. BFRL's comprehensive and

BFRL CRADAs

Adco Products Inc.
Air-Conditioning & Refrigeration Technology Institute
Aladdin Industries
Alerthon Technologies, Inc.
American Association of State Highway Transportation Officials
American Automatrix, Inc.
Andover Controls Corporation
Ashland Chemical Company
Atlas Electric Devices Company
Automatic Logic Corporation
Barber-Colman Company
Carlisle SynTec Systems
Carrier Corporation
Cimetrics Technology, Inc.
Cornell University
Delta Controls, Inc.
Dow Chemical Company
Dow Corning Corporation
Duron, Inc.
E.I. du Pont de Nemours and Co. (2 CRADAs)
Electric Power Research Institute
Enermodal Engineering Limited
Factory Mutual Research Corporation
Firestone Building Products Company
FMC Corporation (2 CRADAs)
General Motors Corporation
GenFlex Roofing Systems
Honeywell, Inc.
Johnson Controls, Inc. (2 CRADAs)
Landis & Staefa
McQuay International
Minnesota Mining and Manufacturing Company
National Elevator Industry, Inc.
National Renewable Energy Laboratory
National Roofing Contractors Association
Orion Analysis Corporation
PlantSTEP, Inc.
PloarSoft, Inc.
Portland Cement Association
PPG Industries, Inc.
PQ Corporation
Roof Consultants Institute
Sekisui America Corporation
Simulation Technologies, Inc.
Teletrol Systems, Inc.
The LORRON Corporation
The Trane Company
United Technologies Corporation
York International

BFRL Consortia

Coatings Service Life Prediction Consortium

Consortium on the Performance of Tape-bonded Seams of EPDM Rubber Roofing Membranes

BACnet Interoperability Testing Consortium

Flammability of Polymer-clay Nanocomposites Consortium

Advanced Environmentally Friendly and Fire-safe Materials

PlantSTEP Inc.

EMCON Alaska, Inc. (Environmental Management Consultants)

National Fire Protection Research Foundation

NSF Center for Advanced Ceramic Based Materials (ACBM)

Multisciplinary Center for Earthquake Engineering Research (MCEER)

Pacific Earthquake Engineering Research Center (PEER)

Mid-America Earthquake Engineering Research Center (MAEC)

Central U.S. Earthquake Consortium (CUSEC)

NEMA Signaling Protection and Communications

diverse laboratory capabilities permit the realization of the development and demonstration of the research results. During 1998, BFRL continued to play an active role in partnering with 14 consortia and served as the lead organization for the first five on the list above.

Fire Detector Industry CEOs Visit NIST

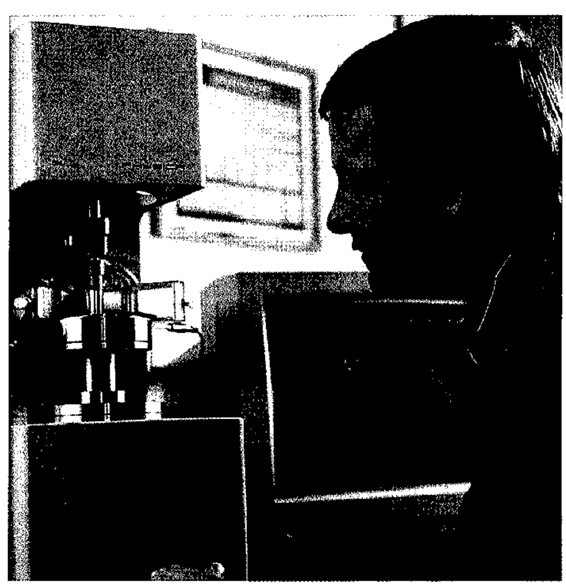
A major component of BFRL's Cybernetic Building Systems objective is the development of advanced fire alarm systems that exhibit enhanced functionality, assure the reliability of building features needed in emergency response, and provide real-time information to the fire service during incidents. These advanced systems have the potential to significantly expand domestic and global markets for the fire alarm industry. Mr. Richard Bukowski, research engineer, invited the CEOs of U.S. major manufacturers to discuss the business implications of the program, obtain their agreement to joint technology development including the provision of industry funding for selected tasks, and ensure that they are willing to produce such products. The result was unanimous agreement that will be formalized through the creation of a consortium.

CMRL Programs Experienced Record Participation Levels in 1998

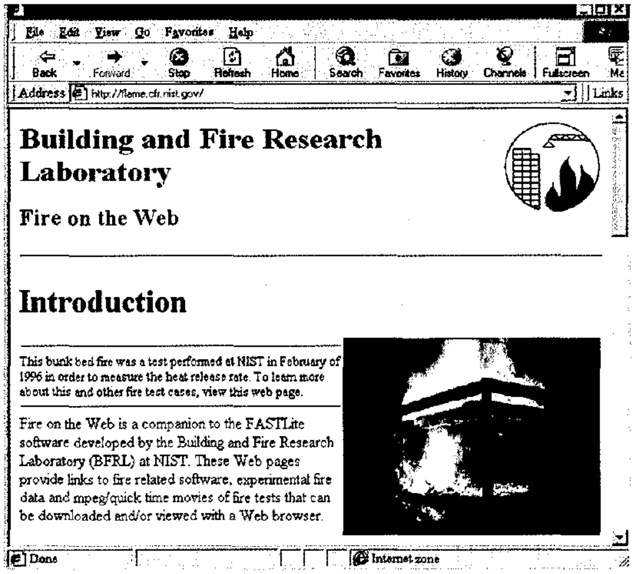
BFRL's Construction Materials Reference Laboratories (CMRL) provide laboratory assessment and proficiency sample programs that promote the quality of testing in construction materials laboratories. CMRL participation in the Cement and Concrete Reference Laboratory (CCRL) and the AASHTO Materials Reference Laboratory (AMRL) grew to over 1,300 laboratories in 1998. Over 750 laboratories participated in the most recent tour of the CCRL Laboratory Inspection Program, while 528 laboratories received assessments by AMRL. Both of these were records. Also, a record was made in the active proficiency sample programs; over 550 laboratories participated in the CCRL Portland Cement Concrete Program and over 600 laboratories in the AMRL Aggregate Proficiency Sample Program. Over 400 laboratories were accredited by the AASHTO Accreditation Program making it the largest accreditor of construction materials laboratories in the United States. AASHTO requires laboratories to participate in AMRL and CCRL programs to receive accreditation.

Implementation of Strategic Highway Research Program (SHRP) Technology

AMRL is assisting AASHTO, FHWA, State Departments of Transportation, and the private sector in expediting the implementation of SHRP technology and the deployment of new technologies in the standards development process. Implementation activities include processing AASHTO provisional standards based on SHRP technology; the addition of SHRP performance graded binder and hot mixed asphalt samples to the AMRL Proficiency Sample Program and inclusion of the standards in the laboratory assessment program; and participation on NCHRP research panels dealing with follow-on research on SHRP technology and the Long Term Pavement Performance Program.



Mr. David Savage, AMRL program supervisor of bituminous programs, conducts test on asphalt binders used in bituminous pavements.



Fire on the Web provides links to BFRL fire-related software

MOU with U.S. Fire Administration

BFRL and the U.S. Fire Administration signed a Memorandum of Understanding (MOU) in November 1997 that allows better coordination of the two agencies' fire safety efforts and improves interaction between the agencies. The MOU will promote participation by the U.S. fire fighting community in the BFRL fire research efforts.

BFRL Collaborating with IBHS

BFRL entered into a Statement of Understanding with the Institute for Business and Home Safety (IBHS) to partner on natural disaster mitigation. Joint planning will focus initially on four activities: identifying technologies that mitigate the impact of natural disasters on people and property; collaborating on hazard assessments that may lead to the development of new technologies including retrofit applications and advancements in design and construction practices to reduce losses; developing technologies that assess the structural integrity and safety of buildings; and developing economical retrofit methods to improve a building's resistance to natural disasters. In addition, BFRL and IBHS will develop disaster education and training programs for insurance underwriters and practitioners in the design and construction industry.

Fire on the Web

The Department of Commerce selected BFRL's *Fire on the Web* as Web Site of the Week for 27 April 1998. This site is a gateway to access software, data, fire videos, and more than a 1,000 reports. It is the FIREDOC search engine. The site is found at www.bfrl.nist.gov/info/fire.html.

FIREDOC EXPRESS

FIREDOC EXPRESS, is a unique service of BFRL's Fire Research Information Services (FRIS) for United States-based companies and organizations to quickly and economically obtain items identified in the FRIS collection of 60,000 fire science and engineering papers, data reports, and multimedia materials. Materials are located through the FIREDOC database search. After the client completes a FIREDOC search, items of interest are selected and the order for loan of those items from the collection is electronically sent to the requester or by overnight mail.

FIREDOC EXPRESS

Timely fire science and engineering services to customers.

Full scale fire test of a Christmas tree conducted in the Large Fire Research Facility by the Fire Safety Engineering Division as part of a fire safety demonstration for a group of Boy Scouts.

Fire Safety Engineering Division Open House

The Fire Safety Engineering Division has conducted several demonstrations for groups ranging from senior fire officials from across the country to local school children. The demonstrations include: experiments that introduce the fundamentals of fire dynamics and fire suppression, an overview of BFRL fire research, and the application of fire research findings to improve the safety of building occupants and fire fighters.

Guest Researchers

Annually, BFRL hosts about 70 visiting scientists from industrial, university, Federal, and foreign laboratories. The length of a typical assignment averages 12 months.

BFRL is active internationally and participates in many international standards-generating organizations. BFRL staff are often invited speakers at international meetings and serve as guest researchers to foreign national laboratories. Data and information are shared between BFRL and our foreign collaborators which influence BFRL's research.

Canada

BFRL and the Institute for Research in Construction are completing a multiyear research project to develop a computer program for promoting acceptable indoor air quality in the design and operation of buildings. The computer program predicts ventilation performance and contaminant levels in a building before construction and analyzes ventilation and indoor air quality in existing buildings.

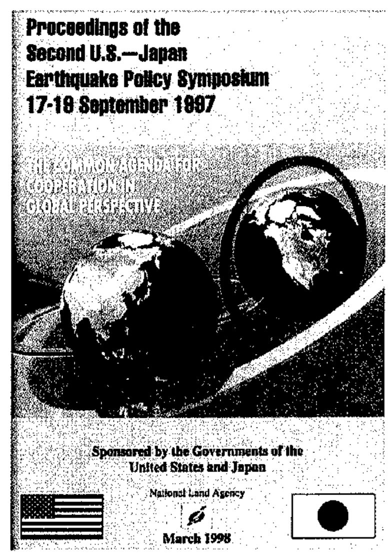
Japan

U.S.-Japan Cooperative Program in Natural Resources

The U.S.-Japan Cooperative Program in Natural Resources (UJNR) was created in 1964, one of three programs comprising the U.S.-Japan Cooperative Science Program. BFRL provides the Chair and Secretariat to two of the most active of the 18 UJNR Panels. They are the Panel on Wind and Seismic Effects and the Panel on Fire Research and Safety.

Panel on Wind and Seismic Effects

The Panel, which has meet annually since its creation in 1969, promotes the exchange of technology for the reduction of damages caused by strong winds, earthquakes, and storm surge and tsunamis. Through the Panel, U.S. and Japanese researchers jointly develop and share seismic and high-wind measurement records and technical data, as well as information on the performance, design, and construction of lifelines, buildings, and other constructed facilities. Research exchanges have advanced technology development in areas such as the effects of seismic and wind loads on steel, concrete, and masonry structures; liquefaction risk analysis; smart materials; and composite and hybrid structures. Joint collaborative research programs have produced improved design and construction practices for both countries. This work is an essential part of U.S. and Japanese member agencies' strategy to stay in the forefront of development of measurement and simulation techniques for the construction industry. Special projects are performed under the auspices of the Panel such as investigations immediately following disasters and comparative analysis of U.S. and Japan's design and construction practices and civil engineering innovations. Panel activities have improved building and bridge standards and codes, and aided structural design and construction and emergency management in Japan and the United States. The Panel offers key perspectives on developments important to the U.S. and Japanese design and construction community, emergency planning and preparedness managers, public health officials, and manufacturers and developers of products for the construction industry. Valuable insight is gained into each country's disaster preparedness methods, wind and seismic measurement techniques,



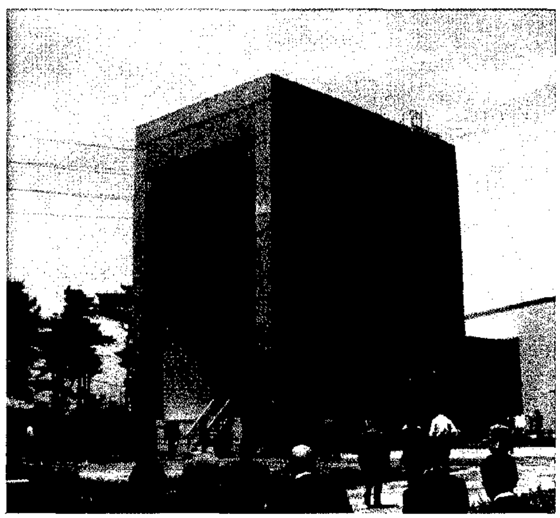
BRFL is active in the U.S.-Japan Common Agenda's Earthquake Mitigation Partnership aimed at accelerating scientific and technological advances to reduce damage to communities from earthquakes.

building on public works design and construction projects, and standards and code systems.

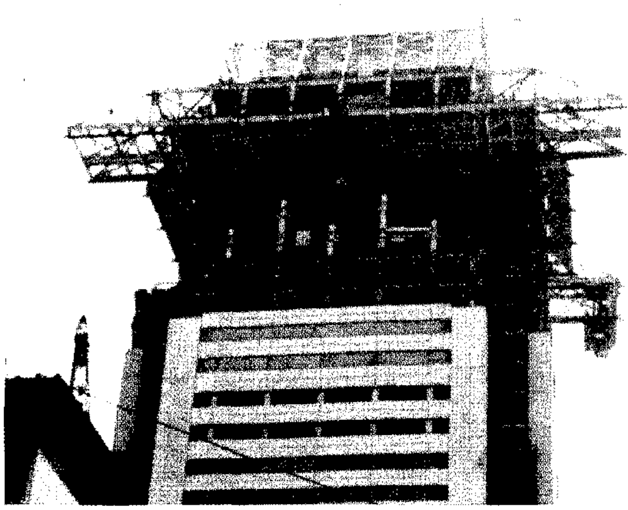
The Panel's activities are planned and approved at its annual meeting and are carried out through collaboration among members working through its 11 task committees: Strong Motion Data and Applications; Testing and Evaluation Procedures for Building Systems; High Performance Structural Systems and Auto-Adaptive Media; Earthquake Engineering for Dams; Design for Wind and Wind Hazard Mitigation; Disaster Prevention Methods for Lifeline Systems; Seismic Information Systems; Soil Behavior and Stability During Earthquakes; Storm Surge and Tsunamis; Wind and Earthquake Engineering for Transportation Systems; and Wind and Earthquake Engineering for Offshore and Coastal Facilities. The Panel's membership includes 18 U.S. agencies, seven Japanese agencies, practitioners and researchers from the private sector, and universities. The Public Works Research Institute provides the Japan-side Chair and Secretariat.

Panel on Fire Research and Safety

The Panel, conducting meetings every 18-24 months, provides the basis for continuing exchange of information, insights into differing approaches to common problems, and sustained collaborative research efforts. As a result, Panel members are able to optimize their collective knowledge so they approach a technically sound and uniform set of fire characterization methods under which manufacturers, designers, specifiers, and regulators can operate confidently. About 40 of the top experts in fire science and fire safety engineering from the United States and Japan represent government research laboratories, fire safety engineering firms, universities, and industrial organizations. The Panel addresses topics such as performance-based fire safety design; toxicity; chemistry and risk and hazard evaluation; materials test methods; fire suppression; fire detection; fire protection engineering tools; large-scale fires; and fire sensing and extinguishment engineering. The hosts for the Japan-side are the Building Research Institute (BRI) and the National Research Institute for Fire and Disaster (NRIFD).



In June, 1998, the UJNR Panel on Fire Research and Safety delegation visited the new BRI facility for studying the effects of wind on urban fire spread.



Technical information exchanges on advanced design and construction technologies with the Japan-side benefit BFRL's structural research program planning. For example, information from Mitsubishi Heavy Industries "T-UP" building which uses automated technologies to raise a 2,000 ton "hat" (the building's roof and cranes that hydraulically lift fabricated floors under the "hat"), is useful for BFRL's Construction Metrology and Automation Group.

Common Agenda's Natural Disaster Reduction

The Common Agenda is an agreement between the President of the United States and the Prime Minister of Japan to join policy level officials and technical specialists from both countries to identify earthquake research and policy issues and seek agreements on cooperative projects to mitigate their impact through improved monitoring and by strengthening research and response countermeasures. BFRL participates in the conduct of the National Disaster Reduction Initiative and the two Panels mentioned above provide technical support.

High Level Forum

The High Level Forum on Earthquake Policy, a component of the Natural Disaster Reduction Initiative is a continuation of the dialogue between the United States and Japan in the area of earthquake hazard reduction policies. The Forum, conducted in October 1998 in Seattle, is an outgrowth of the successful First and Second Earthquake Policy Symposia held in Washington, D.C., in September 1996 and in Kobe, Japan in September 1997. The 1998 Forum addressed four central themes:

- the use of real-time seismic information systems;
- the use of earthquake loss estimation models;
- post-earthquake response and recovery policies; and
- earthquake mitigation and the prevention of future losses.

The Forum participants agreed to create a sub-group to develop strategies for exchanging information on earthquakes and earthquake damages; post-earthquake emergency response; long-term recovery strategies and programs; and identifying programs to reduce damage to structures. The strategy's development will be coordinated by the Federal Emergency Management Agency and the National Land Agency, Japan, the respective Co-Chairs; the strategies will be augmented through the UJNR Panels (see pages 41 and 42).

Assessment of Liquefaction Potential Using Shear Wave Velocity Measurements

Working in partnership with researchers, designers, and builders in the U.S. and Japan, Dr. Ronald Andrus, research civil engineer, and BFRL researchers developed experimentally-validated criteria for predicting the potential for liquefaction, a major cause of damage in earthquakes, using measurements of shear wave velocity in the ground. Final guidelines will document the new procedure in 1999 based on ongoing trials within the user community and a workshop that will seek to reach consensus on a draft document compiled in October 1998. The procedure, which will aid the design and rehabilitation of structures and lifelines in earthquake-prone regions, has been validated through case history data, the largest effort of its kind, from over 25 earthquakes and 70 measurement sites. Data for 20 of these sites were obtained during a two-week trip to Japan in 1998 which included visits to several government laboratories, universities, and companies. The procedure was used in several construction projects and is a promising alternative to the commonly used penetration-based procedures. It is expected to supplant existing methods in soils that are hard to sample such as gravelly soils, and at sites where borings may not be permitted, such as capped landfills, because of its many advantages, including the non-intrusive nature of testing required in the field.

Kingdom of Saudi Arabia

Mr. Joel Zingeser, manager, Codes and Standards Services, leads a joint BFRL and NIST Technology Services Program aimed at helping the Kingdom of Saudi Arabia (KSA) develop and adopt a building code based on U.S. practices. This bilateral work will help the U.S. construction industry in major developing markets avoid technical barriers to trade and promote the application of U.S. technology in international construction markets through the development and adoption of appropriate building and construction practices, codes, specifications, and standards. Work with KSA is being conducted under two Memoranda of Understandings between NIST/ BFRL and the National Conference of States on Building Codes and Standards and with the Saudi Arabia Standards Organization (SASO). The Saudi Building Code Coordination Committee and its four technical committees are coordinating this work in Saudi Arabia. In addition to SASO, participants in the KSA code review and development process represent private sector organizations, universities, and other key departments of government. U.S. technical support for the KSA efforts has come from the International Conference of Building Officials, whose Uniform Building Codes are the basis for the Saudi effort, and from the National Fire Protection Association, and other members of a U.S. steering committee. It is expected that completion of the draft of the first components of the Saudi code will be completed in 1999.

Korea

Two guest workers from Korea joined Structures Division research teams. During a six-month period, Mr. Sang-Yun Kim of the Korea Institute of Nuclear Safety is examining current seismic design provisions for anchorage to concrete. Dr. Jang Hwa Lee of the Korea Institute of Construction Technology works in the areas of nondestructive evaluation and structural intensity assessment of concrete structures.

Switzerland

Dr. Chiara Ferraris, physicist, spent six-weeks during the summer of 1998, as a visiting scientist at the Swiss Federal Institute of Technology, Lausanne. There, she conducted research in characterizing the adsorption of high range water reducing admixtures on cement using acoustophoresis. Dr. Ferraris presented several talks on BFRL's work in rheology and alkali-silica reaction stress measurements.

Multilateral Activities

International Committee Participation

International Council for Research and Innovation in Building and Construction (CIB)

BFRL is a Full Member of CIB and actively participates in many of its task groups and working commissions. CIB is concerned with fostering international cooperation and information exchange in building construction and research, technology development, and documentation and provides an important channel for international pre-standardization activity in this field. CIB priorities include sustainable development, performance-based standards, construction process re-engineering, better serving the needs of members in the Americas and Asia, and expanding its role as a pre-standardization body.

Dr. Jack Snell, BFRL Deputy Director, is CIB's Vice President, member of the Board of Directors, and serves on the Program Committee.

Ms. Barbara Lippiatt, economist, delivered an invited talk on her Building for Environmental and Economic Sustainability (BEES) tool for selecting cost-effective green building products at the triennial CIB World Building Congress in Sweden in June. The theme of the congress was "Construction and the Environment."

Mr. Richard Bukowski, research engineer, chairs the CIB W14 on Fire, TG1, Engineering Evaluation of Building Fire Safety Performance on harmonizing the engineering analysis approaches being developed in various countries in support of performance-based codes. Mr. Bukowski also represents BFRL in CIB TG11 on Performance Building Codes. He and Dr. Walter Jones, leader, Fire Safety Systems Group, are participating in a W14 activity to conduct round robin evaluations of fire models against experimental data.

International Organization for Standardization (ISO)

The Working Group on Design Life of Buildings of the International Organization for Standardization (ISO), established in 1993 with Dr. Geoffrey Frohnsdorff, chief, Building Materials Division, as chairman, has been elevated to a subcommittee (SC) status within ISO (TC59/SC14, Design Life). This reflects the high level of activity in the WG and the broad international interest in its subject. The SC will continue to develop standards/guides for service life planning, prediction of service life of materials and components, auditing designs and maintenance plans for consistency with the design life, data formats, and life-cycle costing.

Dr. Richard Gann, chief, Fire Science Division, has been named U.S. Expert to the Working Group on Prediction of Toxic Effects of the ISO TC92 Committee on Fire Safety.

Mr. James Pielert, leader, Construction Materials Reference Laboratory, chairs ASTM Subcommittee C09.02 on International Activities. C09.92 is the U.S. Technical Advisory Group (TAG) for ISO TC71

Subcommittee 1 on Testing of Concrete. The role of the TAG is to coordinate reviews of draft standards and to submit U.S. standards for consideration by ISO. The TAG has coordinated a review of draft concrete test standards prepared by the Subcommittee and was successful in getting changes made to bring them into closer conformance to U.S. practice.

Mr. Steven Bushby, electronics engineer, is Convener of ISO TC 205 WG 3 Building Control System Design. The Working Group is developing a multipart international standard that addresses several issues related to building control systems issues including control system functionality, communication protocols, system specifications, and project management. ANSI/ASHRAE Standard 135-1995 was adopted as the working draft for the communication protocol portion of this Standard.

ISO's Technical Committee (TC)86, Refrigeration and Air-conditioning is composed of eight subcommittees that address topics such as terms and definitions, safety, and testing and rating methods for refrigeration and space-conditioning equipment. BFRL participates as a member of the U.S. Technical Advisory Group for ISO TC86. BFRL also is represented on WG1 and WG5, within Subcommittee (SC)6, factory-made air-conditioning and heat pump units. WG1 is working to revise testing and rating standards that apply to unitary air-conditioners and heat pumps. WG5 is developing testing and rating standards that cover three categories of multisplit air-conditioners and heat pumps.

Mr. Joel Zingeser, manager, Standards and Codes Services, is NIST's representative on ISO Technical Advisory Group (TAG)8 on Building. TAG8 is appointed by ISO's Technical Management Board. Approximately 12 countries are represented. TAG focusses on advancing and streamlining building sector activities within the relevant ISO Technical Committees and their Subcommittees.

International Union of Testing and Research Laboratories for Materials and Structures (RILEM)

RILEM promotes progress in the design, testing, manufacture and use of building materials. Its membership includes specialist from 80 countries involved with construction and research.

Mr. James Pielert, leader, Construction Materials Reference Laboratory, is the NIST delegate to RILEM and is a member of the Bureau, the management committee of RILEM. He attended the RILEM annual meeting where development of a strategic plan for RILEM was begun.

Dr. Walter Rossiter, research chemist, chairs RILEM/CIB Joint Committee on Roofing Materials. The committee's objectives are to develop a methodology of assessing the condition of in-place low-sloped roofing membranes and determine the state-of-the-art design, application, and maintenance of sustainable low-sloped roofing systems.

Dr. Long Phan, research structural engineer, is a member of RILEM Committee 129-MHT, Test Methods for Mechanical Properties of Concrete at High Temperatures. The committee is working on developing technical recommendations for test methods to measure strength, elastic, and inelastic properties of concrete at elevated temperatures.

Process Industries Executive for Achieving Business Advantage using Standards for Data Exchange (PIEBASE)

PIEBASE is an international umbrella organization for process and construction industry consortia active in the development of ISO STEP (Standard for The Exchange of Product model data) application protocols and other international standards for exchanging and sharing industrial data. Mr. Mark Palmer, research mechanical engineer, participates on the PIEBASE Executive Board and leads the PIEBASE Working Group 2 on process plant engineering activity models and Working Group 4 developing an industry roadmap for information technology standards.

International Energy Agency (IEA)

Eleven countries participate in the International Energy Agency Annex 34. Members of the U.S. team, in addition to Dr. George Kelly, leader, Mechanical Systems and Controls Group, include Johnson Controls Inc., the Honeywell Center, Massachusetts Institute of Technology, Purdue University, and Field Diagnostic Services, Inc. Annex 34 works with control manufacturers, industrial partners, and/or building owners and operators to demonstrate the benefits of on-line performance evaluation in real building applications. The fault detection and diagnostic (FDD) methods developed in an earlier Annex (Annex 25) are being combined into a robust performance evaluation systems and incorporated into a future generation of smart building control systems.

Forum for International Cooperation on Fire Research (FORUM)

The Forum for International Cooperation on Fire Research (FORUM) comprises heads of public and private sector fire research laboratories and organizations sponsoring fire research around the world. Dr. Jack Snell, BFRL Deputy Director is the Forum Chair and Mr. Richard Bukowski, research engineer, is Secretary. The group meets annually at the facilities of one of the member organizations to discuss mutual interests; encourage cooperative undertakings; and promote the advancement of fire safety engineering. The 1998 FORUM meeting was hosted by NIST at its Gaithersburg facilities and featured a two-day symposium on International Harmonization of Performance-based Fire Safety. Further information on FORUM and its members and activities is found on BFRL's Web site at http://www.bfrl.nist.gov/info/forum/forum.html.

Thermal Insulation Reference Materials

The Building Environment Division and NIST's Information Technology Laboratory are organizing a three-year effort to examine the differences, if any, between regional thermal insulation reference materials in Canada, France, Japan, and the United Kingdom. In the first phase, the participating laboratories have approved the test protocol, identified candidate regional reference materials, obtained the materials, and prepared test specimens. In accordance with test protocol, measurements of thermal conductivity are to be conducted with guarded-hot-plate apparatus conforming to either ASTM Test Method C177 or ISO 8302. The measurements are to be conducted from 280 K to 340 K at a temperature difference of 20 K across the specimen. Replicate measurements at 297 K also are required. In phase two, which begins in 1999, the material variability characterization and actual test measurements are scheduled.

One of the great strengths of the Laboratory is the excellence of its staff. Their competence and contributions are consistently recognized by peers in professional societies. Examples of recent staff recognitions and appointments are listed.

Structural Engineering Institute Walter P. Moore Jr. Award

Dr. Richard Marshall, retired, was the first recipient of the Structural Engineering Institute of ASCE Walter P. Moore Jr. Award for technical excellence in and dedication to the development of structural engineering codes and standards. The award was made in recognition of his many contributions to the development of ASCE 7, Standard on Minimum Design Loads for Buildings and Other Structures. Dr. Marshall's contributions date back to the late 1960s when the forerunner of ASCE 7, ANSI A58.1, was managed and coordinated at NIST. More recently, Dr. Marshall played a substantial role in the development of the technical provisions of the wind load section.

1998 Robert L'Hermite Award

The International Union of Testing and Research Laboratories for Materials and Structures (RILEM) selected Mr. Dale Bentz, chemical engineer, as the 1998 recipient of the prestigious Robert L'Hermite Medal for his outstanding achievements in computer modeling the formation and physical properties of cementitious materials. Bentz's paper, "Three-Dimensional Computer Simulation of Portland Cement Hydration and Microstructure Development," is one of the few papers on cement that have ever been selected to be the feature article in the *Journal of the American Ceramic Society.* The jury honors Mr. Bentz for his "creative contributions to the early teamwork and for the subsequent broadening of the model to describe a wide range of physical properties in a 3-dimensional approach." Also, the jury recognized Mr. Bentz's innovative use of the model in training and teaching courses.

Roon Award, Federation of Societies for Coatings Technology

Dr. Tinh Nguyen, physical scientist, was the co-recipient of the Roon Award of the Federation of Societies for Coatings Technology (FSCT) for his work in the development of an experimentally verified physics-based model for predicting the delamination rate of polymer coatings from steel substrate subject to corrosion. The model is useful to design better coatings for protecting steel against corrosion. Roon Awards are the most prestigious scientific awards given by the FSCT. The awards recognize the best invited technical papers presented at the Federation Annual Meeting.

Distinguished Young Engineer of 1998

Mr. Dale Bentz, chemical engineer, was selected by the Maryland Science Center to receive a Distinguished Young Engineer of 1998 Award for his work on the simulation of the properties and perfor-

Dr. Sieglinde Fuller, economist, was selected by DOE as an "Energy Champion" for the Department of Commerce. She is recognized for her work in developing and updating the life-cycle cost methodology and software for the Federal Energy Management Program (FEMP). Dr. Fuller is featured on this poster and on the web in FEMP's "You Have the Power" campaign which was launched to bolster energy awareness across the Federal government.

mance of complex cement-based materials beginning with knowledge of the shapes and sizes of, and phase distributions within, cement particles.

ACI Structural Research Award

Ms. Geraldine Cheok, research structural engineer, and Dr. William Stone, leader, Construction Metrology and Automation Group, received the 1997 American Concrete Institute (ACI) Structural Research Award for their papers describing tests on, and developing guidelines for, precast moment frames using mild steel and post-tensioned tendons to develop the connections.

ACI's 1998 Arthur R. Anderson Award

The American Concrete Institute selected the NSF Center for Science and Technology of Advanced Cement-Based Materials (ACBM) the recipient of the 1998 Arthur R. Anderson Award "for noteworthy research leading to significant contributions to the understanding of cement based materials." ACBM is led by Northwestern University and its partners are the University of Illinois, Purdue University, the University of Michigan, and NIST's Building and Fire Research Laboratory.

ASCE Committee Chair

Dr. William Stone, leader, Construction Metrology and Automation Group, accepted the Chair of ASCE's Committee on Field Sensing and Robotics and will serve as the Technical Chair of the Robotics 2000 Conference.

ASCE's Structural Engineering Institute Certificate of Appreciation

Mr. James Pielert, leader, Construction Materials Reference Laboratory, received a Certificate of Appreciation from the Structural Engineering Institute of the American Society of Civil Engineers for chairing the Standards Committee on Structural Condition Assessment and Rehabilitation of Buildings. The citation specifically recognized his contributions in preparing a revision of ASCE 11 "Guideline for Structural Condition Assessment of Existing Buildings."

Board of Direction, Building Seismic Safety Council

Dr. H.S. Lew, senior research structural engineer, was elected to serve for a two-year term on the Board of Direction of the Building Seismic Safety Council. Dr. Lew will represent the Interagency Committee on Seismic Safety in Construction.

ASTM Award of Appreciation

Dr. Andrew Persily, leader, Indoor Air Quality Group, was presented an Award of Appreciation from ASTM Committee D22 on Sampling and Analysis of Atmospheres for his leadership as chair of the Related Factors Section of Subcommittee D22.05 on Indoor Air and for his dedication and technical contributions to committee's symposia program and to the development of new standards that have advanced the science of sampling and analysis of indoor atmospheres.

Board of Governors, Structural Engineering Institute

Dr. H.S. Lew, senior research structural engineer, was appointed to serve for a three-year term on the Board of Governors of the Structural Engineering Institute (SEI) of the American Society of Civil Engineers (ASCE). SEI, which operates under the umbrella of ASCE, is a new organization established for the structural engineering community.

Firesafety Board

Ms. Kathy Notarianni, research fire protection engineer, has been named to the Firesafety Board of Advisors Center for Firesafety Studies at the Worcester Polytechnic Institute (WPI). WPI has been offering a master's degree in fire protection engineering for 20 years and will shortly graduate its first Ph.D. students. The Board advises the Department on its evolving curriculum, student recruiting, and the identification of educational materials. Ms. Notarianni is the first graduate of the WPI program to serve on the Board.

Papers Chairman, The Combustion Institute

Dr. William Pitts, research chemist, was named Papers Chairman for the first joint meeting of the three regional U.S. sections of The Combustion Institute. The meeting will be held in the spring of 1999. The Combustion Institute is an educational non-profit, international, scientific society whose purpose is to promote and disseminate research in combustion science. The Institute also publishes the scientific journal *Combustion and Flame.*

The Bronze Medal Award recognizes work that has resulted in more effective and efficient management systems and the demonstration of unusual initiative or creative ability in developing and improving methods and procedures and recognizes significant contributions affecting major programs, scientific accomplishment within NIST, and superior performance of assigned tasks for at least five consecutive years.

Australian Molecular Modeling Workshop

Dr. Marc Nyden, research chemist, was an invited participant in the 3rd Australian Molecular Modeling Workshop. The workshop papers covered a range of topics including protein structure and function, computational chemistry, materials science, drug design, and bioinformatics. Dr. Nyden's paper was the only one on thermal reactivity in polymers.

Invited Paper

Dr. Marc Nyden, research chemist, and Dr. Jeffrey Gilman, research chemist, prepared an invited paper for a special issue of the journal *Computational and Theoretical Polymer Science* in honor of Bruce Eichenger. Formerly at the University of Washington and now at Molecular Simulations, Inc., Dr. Eichenger is a pioneer and international leader in the field of molecular modeling of polymers.

Service Life Prediction of Coatings

Dr. Jonathan Martin, leader, Organic Building Materials Group, chaired the 1st International Conference on Service Life Prediction Methodologies for Coatings held in Breckenridge, Colorado; he also chaired the conference organizing committee.

NFPA Committee on Residential Sprinkler Systems

Mr. Daniel Madrzykowski, leader, Large Fire Research Group, was selected Chair of the Technical Committee on Residential Sprinkler Systems of the National Fire Protection Association. The committee develops standards for installing sprinkler systems in homes. The standards are designed to provide sprinkler systems that prevent fire flashover, thereby increasing the time for residents to escape. The committee also considers new technologies that are appropriate for inclusion in the standards.

1998 NIST Bronze Medals

Mr. Dale Bentz, chemical engineer, was awarded the NIST bronze medal for his contributions, individually and in collaboration with others, to construction materials research. Many of his more than 100 publications describe the development and application of models for simulating the performance of cement and concrete, a subject of great importance to the nation's civil infrastructure. The models have significantly advanced the understanding of relationships among the composition, microstructure, physical properties, mechanical properties, and engineering performance of concrete.

Ms. Sheilda Bryner, division secretary, Building Environment Division, was awarded the NIST bronze medal for her outstanding administrative support during the period 1995 to 1998 when she was simultaneously secretary to the Building Environment Division, secretary to the Source Evaluation Board and to the program manager of the Vapor Compression Refrigeration Technology focused program in the NIST Advance Technology Program, and administrative assistant to the president of the 55,000-member American Society of Heating, Refrigerating, and Air Conditioning Engineers.

BFRL Communicator Award

Ms. Geraldine Cheok, research structural engineer, and Dr. William Stone, leader, Construction Metrology and Automation Group, received BFRL's Communicator Award for research with industry and a series of publications and presentations leading to the development of seismically resistant connections for precast concrete frames and the acceptance of these high performing systems by national standards and building codes.

BFRL Communication Award

Dr. Kevin McGrattan, mathematician; Dr. Howard Baum, NIST Fellow; Mr. William Walton, senior fire prevention engineer; and Dr. Javier Trelles, postdoctoral researcher from the University of California, Berkeley, earned BFRL's Communication Award for their seminal work in *Smoke Plume Trajectory from In Situ Burning of Crude Oil in Alaska - Field Experiments and Modeling of Complex Terrain.* This work led to the acceptance of in situ burning as an environmentally desirable and economical choice for many oil spills on water.

BFRL staff maintains close communication with constituents through scheduling significant events addressing leading edge technologies and helping facilitate the transfer of new knowledge at the grass roots. The following highlights provide a sample of BFRL's 1998 events.

Rehabilitation Using Fiber-Reinforced Polymer (FRP) Composites

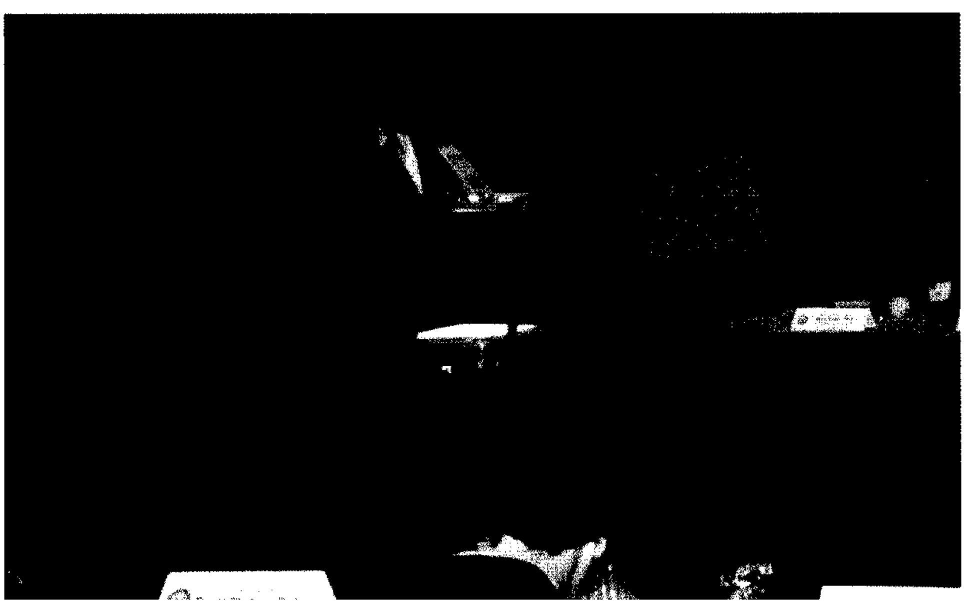
A significant percentage of the Nation's infrastructure is in need of repair and retrofit due to exposure to de-icing salts or the natural environment, higher service loads, or more stringent seismic or blast requirements. The market for structural rehabilitation, which encompasses both of these activities, is potentially in the billions of dollars. Fiber-reinforced polymer (FRP) composites show promise in structural rehabilitation when compared with traditional materials for rehabilitation such as steel. This was the subject of a workshop held by the BFRL Structures Division in January 1998 in Tucson, Arizona, that brought together 27 specialists divided evenly among academia, industry, and government. The event created a road map for development of standards on using FRP composites in structural rehabilitation. The workshop concluded that standards for structural rehabilitation using FRP composites are urgently needed and are being addressed at an uneven pace. Most advancements are design standards for seismic retrofit of RC columns. Some work has already been done for beams. Much work must be accomplished on walls. Also, some ASTM material properties tests, intended for the aerospace and automotive industries, need to be adapted for use in construction applications. The participants identified the following research priorities:

- fire resistance of FRP composites, especially as their use expands from highway bridges to buildings;
- durability against exposure to moisture, saline environment, thermal cycles, freeze-thaw, and ultraviolet radiation;
- non-destructive evaluation methods for inspection and in-service monitoring; and
- need for a national repository of data on material properties, structural tests, and field application of FRP.

Dr. Dat Duthinh, research structural engineer, is leading BFRL's project on FRP composites in construction.

Planning Design Guidelines for FRP Structures

Dr. Joannie Chin, materials research engineer, planned and scheduled a workshop at NIST, Gaithersburg, Maryland in July 1998 on the development of design guidelines for fiber-reinforced polymer (FRP) composite structures. The workshop involved 20 participants from FRP composite manufacturers and suppliers, universities, and government agencies. Participants discussed and made recommendations for FRP design guidelines for civil engineering applications. The workshop will be followed by a second meeting in 1999 at which plans for establishing a government/industry/university consortium on FRP composite structures will be formalized. At the



Dr. George Mulholland, research chemist, is addressing the Department of Defense Next Generation Fire Suppression Technology Program (NPG) principals. NPG members are identifying techniques to achieve the goal of developing alternative fire fighting technologies to halon 1301, by 2005, that can be economically implemented in aircraft, ships, land combat vehicles, and critical mission support facilities.

workshop, participants discussed the use of load and resistance factor design principles as the basis for FRP design. Critical issues cited included long-term durability, fire performance, and industry-wide standardization of components.

ASHRAE/NIST 3rd Refrigerant Conference

Refrigerant options for air-conditioning and refrigeration industry in response to ozone depletion and climate change were the topic of the third refrigerant conference *Refrigerants for the 21st Century* jointly organized by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers and NIST was held during 6-7 October 1998 at NIST, Gaithersburg, Maryland. Climate change is the next global environmental problem. The conference program was based on 16 invited presentations, which were given by international experts. The topics included contemporary and future fluorochemicals; "natural fluids" such as hydrocarbons, carbon dioxide and air, secondary loop systems using ammonia and other chemicals; and not-in-kind technologies. BFRL's contributors included Dr. David Didion, NIST Fellow and a co-author of two papers and Dr. Piotr Domanski, leader, Thermal Machinery Group, who chaired the conference steering committee. The conference provided a forum for presenting different points of view on the best refrigerant options for the future. The need for this dialog will increase as a result of the intensifying international climate change negotiations.

Life-Cycle Costing Workshops

Since the first oil crisis in the early 1970's, BFRL's Office of Applied Economics (OAE) has taught two-day workshops on life-cycle cost (LCC) analysis of energy and water conservation projects in federal buildings. The workshops help architects, engineers, energy analysts, and building managers meet, in a cost-effective manner, the goal of the federal government to reduce energy consumption in its buildings by 30 percent by 2005 from 1985 levels. The LCC methodology taught in the workshops is supported by a computer program, BLCC (Building Life-Cycle Cost Analysis), developed by OAE under sponsorship of the DOE Federal Energy Management Program (FEMP). The workshops are taught several times each year in various locations across the United States. About 2000 people from federal, state, and local agencies and the private sector have taken the workshop and are now practicing life-cycle costing to evaluate federal investments in energy and water conservation.

In recent years, the workshop also has been taught by private-sector instructors who were OAE trained. In 1996, the OAE added to the curriculum a more advanced, project-oriented workshop that emphasizes the application of the BLCC program to complex, real-world problems. In 1997, OAE economists taught an interactive, televised, two-hour introduction to LCC analysis to which 65 sites were linked. OAE staff follow up the workshops with technical support to practitioners of LCC analysis and users of BLCC and work closely with DOE/FEMP to include new developments in energy conservation policy and legislation in the workshop materials and in the software. In a recent study, DOE/FEMP estimated that between 1985 and 1994 its energy conservation program, of which BLCC is an integral part, has saved close to $1 billion a year, which amounts to five dollars for each dollar invested, at an annual rate of return of 25 percent.

2nd NGP Workshop

BFRL organized and chaired the second meeting of the principal investigators under the Department of Defense Next Generation Fire Suppression Technology Program (NGP) held in Rockville, Maryland. Forty experts in the field of fire suppression presented results from the program which is aimed at the development of new processes, techniques, and fluids for replacing halon 1301 for firefighting. The results included:

- Identification of effective chemicals with little adverse environmental impact;
- New concepts for high efficiency powders;
- Toxicity assessment method with maximum realistic exposures;
- First apparatus for screening the effectiveness of gaseous, liquid droplet, and powdered agents on flames;
- Definition of the penalties from different types of clutter;
- Monitoring the agent and combustion products during actual weapons systems fire tests.

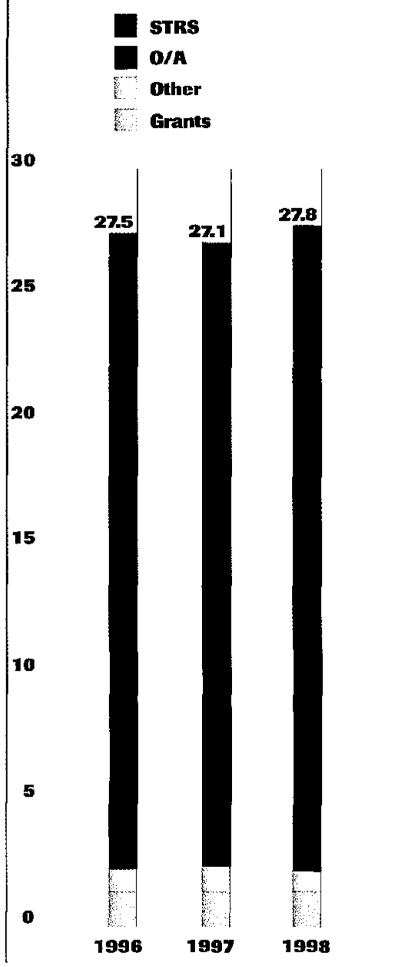
BFRL Resources 1996-98 ($ millions)

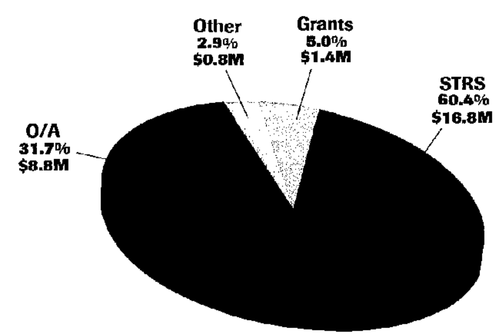
STRS — In-house research, NIST congressionally appropriated funds

O/A — In-house research, other agency funds

Other — Other funds including industry and private sector

Grants — Grants to other organizations including academia





Organizations Funding BFRL's Research

Funding from other federal agencies and industry supports about one-third of BFRL's overall research during FY 1998. We are proud to serve our federal and industry customers with measurement technologies. They are recognized in the following list:

FEDERAL AGENCIES

- **Department of Agriculture**
- **Department of Defense Agencies**
- **Department of Energy**
- **Department of Health and Human Services**
- **Department of Housing and Urban Development**
- **Department of Interior**
- **Department of Justice**
- **Department of Labor**
- **Department of State**
- **Department of Transportation**
- **Department of Treasury**
- **Environmental Protection Agency**
- **Federal Emergency Management Agency**
- **General Services Administration**
- **National Aeronautics and Space Administration**
- **National Science Foundation**
- **Nuclear Regulatory Commission**

PRIVATE SECTOR

- **Air-conditioning and Refrigerating Technology Institute**
- **American Association of State Highway & Transportation Officials**
- **ASTM**
- **Northwestern University**
- **Virginia Department of Transportation**
- **Coating Consortium**
- **Dow Chemical Company**
- **Fire Safe Materials Consortium**
- **General Motors Corporation**
- **Nanocomposites Consortium**
- **Johnson Controls, Inc.**
- **Roofing Consortium**
- **Sleep Product Safety Council**
- **Trane Company**

BFRL Organization at a Glance

The **Structures Division** promotes construction productivity and structural safety by providing measurements and standards for key technologies supporting the design, construction, and serviceability of constructed facilities including infrastructure lifeline systems. Work includes:

- performing and supporting laboratory, field, and analytical research in structural evaluation and standards, structural systems and design, and construction metrology and automation, which includes non-destructive structural evaluation; high-performance materials for new construction and repair and rehabilitation of existing structures; performance of structural systems; structural control and performance based seismic design; wind loads on structures; structural fire endurance; specialized testing of structural components, connections, and systems; performance standards for structural design, and improved construction practices;
- developing construction site metrology and data telemetry standards for construction simulation and 3D visualization, machinery/vehicle monitoring and control, and automated component placement and robotics;

■ conducting legislatively mandated research for improving seismic design and construction practices and investigations of important structural failures, including failures during construction, to assess the effectiveness of structural design and construction practices and to identify areas for improvement; and
■ providing technical support to the National Earthquake Hazards Reduction Program (NEHRP) and to standards and code development organizations for constructed facilities.

Contact: Dr. S. Shyam Sunder
Chief, Structures Division
(301) 975-6713
sunder@nist.gov

The **Building Materials Division** performs research to advance construction materials science and technology and disseminates improved techniques and data to make more informed decisions about the performance of construction materials. Work includes:
■ conducting analytical, laboratory, and field research;
■ developing measurement and prediction methods of service life to serve as the technical bases for improved criteria and standards for evaluation, selection, use, and maintenance of construction materials, and improved tools to aid the making of decisions concerning construction materials;
■ providing technical support to national and international standards-writing organizations such as ASTM and the International Organization for Standardization; and
■ conducting cooperative programs with other research organizations, professional societies, standards-writing groups, testing laboratories, and educational institutions.

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The **Building Environment Division** provides technologies to reduce the cost of designing and operating buildings and increase the international competitiveness of the U.S. building industry. This includes:
■ providing modeling, measurement, and test methods needed to use advanced computation and automation effectively in construction and to improve the quality of the indoor environment and the performance of building equipment;
■ conducting laboratory, field, and analytical research on building mechanical and control systems;
■ developing data, measurement methods, and modeling techniques for the performance of the building envelope, its insulation systems, building air leakage, the release, movement and absorption of indoor air pollutants; and
■ developing software performance criteria, interface standards, and test methods needed for the Nation's building industry to make effective use of modern computer-aided design hardware and software and database management systems.

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The **Fire Safety Engineering Division** develops methods to predict the behavior of fire and smoke and assess various means to mitigate the impact of fire on people, property, and the environment. This includes:
■ developing and demonstrating the application of analytical tools to building fire problems;
■ developing analytical models for the quantitative prediction of the threats to people and property from fires and the means to assess the accuracy of those models; developing techniques to predict, measure the behavior, and mitigate the impact of large fires; and
■ operating the Fire Research Information Service and the fire research large-scale fire test facility.

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The **Fire Science Division** performs research on and develops scientific and engineering understanding of fire phenomena and metrology for fire research. This includes:

- producing principles, metrology, data, and predictive methods to characterize fires, the burning of polymeric materials, and their effluents; and
- developing science and predictive methods to enable high-performance fire detection and suppression systems.

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The **Office of Applied Economics** supports BFRL's research by providing standardized economic methods, economic models, training programs and materials, and expert technical consulting in support of resource allocation decisions; and uses techniques such as benefit-cost analysis, life-cycle costing, multi-criteria decision analysis, and econometrics to evaluate new technologies, processes, government programs, legislation, and codes and standards to determine efficient alternatives.

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The **Office of Cooperative Research Programs** facilitates the transfer of scientific and technical output of the Building and Fire Research Laboratory to the user community; manages the cooperative building and fire research programs with other federal agencies and national and international private organizations; and develops cooperative research programs with other federal agencies and agencies of foreign governments.

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More Information About BFRL

- ***Publications 1997,*** an annual listing of BFRL's publications with indexes for abstracts, authors, and keywords is available as hard copy and on 2-CD-ROMs, NIST SP 929, May 1998. Also, full text of publications with art from 1994 to present are available from BFRL Publications On-line at http://flame.cfr.nist.gov/bfrlpubs/.
- ***BFRL Research Updates,*** BFRL's periodic newsletter. They are available at http://www.bfrl.nist.gov/bfrlnews/newstoc.html.
- ***Building and Fire Research Project Summaries:*** an annually prepared description of BFRL's ongoing research. The summary is available online at http://www.bfrl.nist.gov/860/ps98/.

Ordering Instructions: To order a copy of these free publications or to discuss BFRL's research reports, contact Nora Jason, BFRL Information Service, 301-975-6862, nora.jason@nist.gov.

Visit the Laboratory

Potential collaborators are encouraged to visit BFRL when in the Washington area. To schedule a visit, contact Dr. James Hill, Deputy Director (Acting), Building and Fire Research Laboratory, james.hill@nist.gov

BFRL Inquiries

Questions about specific programs should be directed to BFRL's Management listed in the Chapter, BFRL Finances & Organization. If you have general questions about BFRL programs or are interested in working with BFRL, contact:

- Dr. Richard N. Wright, BFRL Director, richard.wright@nist.gov
- Dr. Jack E. Snell, BFRL Deputy Director, jack.snell@nist.gov

The mailing address for all BFRL personnel is:

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NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

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- a grassroots **Manufacturing Extension Partnership** with a network of local centers offering technical and business assistance to smaller manufacturers; and
- a highly visible quality outreach program associated with the **Malcolm Baldrige National Quality Award** that recognizes business performance excellence and quality achievement by U.S. manufacturers, service companies, educational organizations, and health care providers.

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