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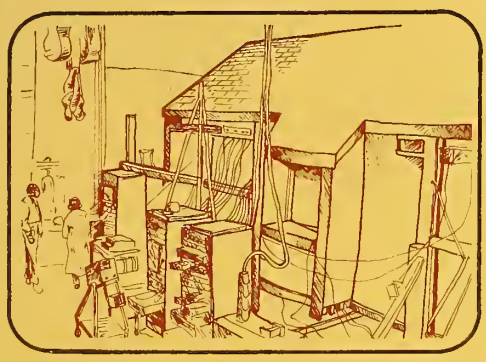
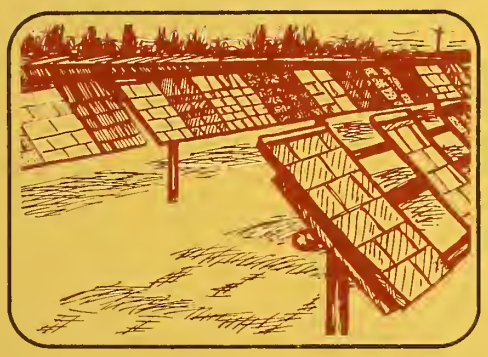
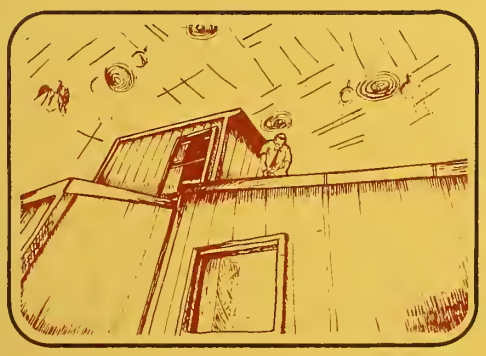


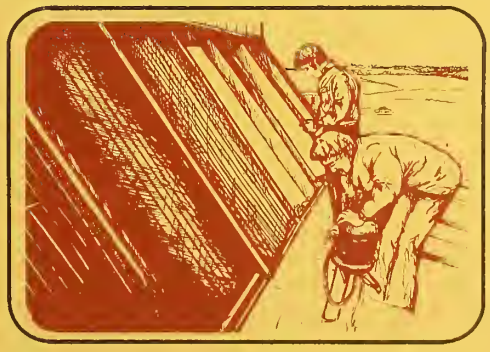
The CENTER for BUILDING TECHNOLOGY

Institute for Applied Technology
National Bureau of Standards
Department of Commerce

a perspective







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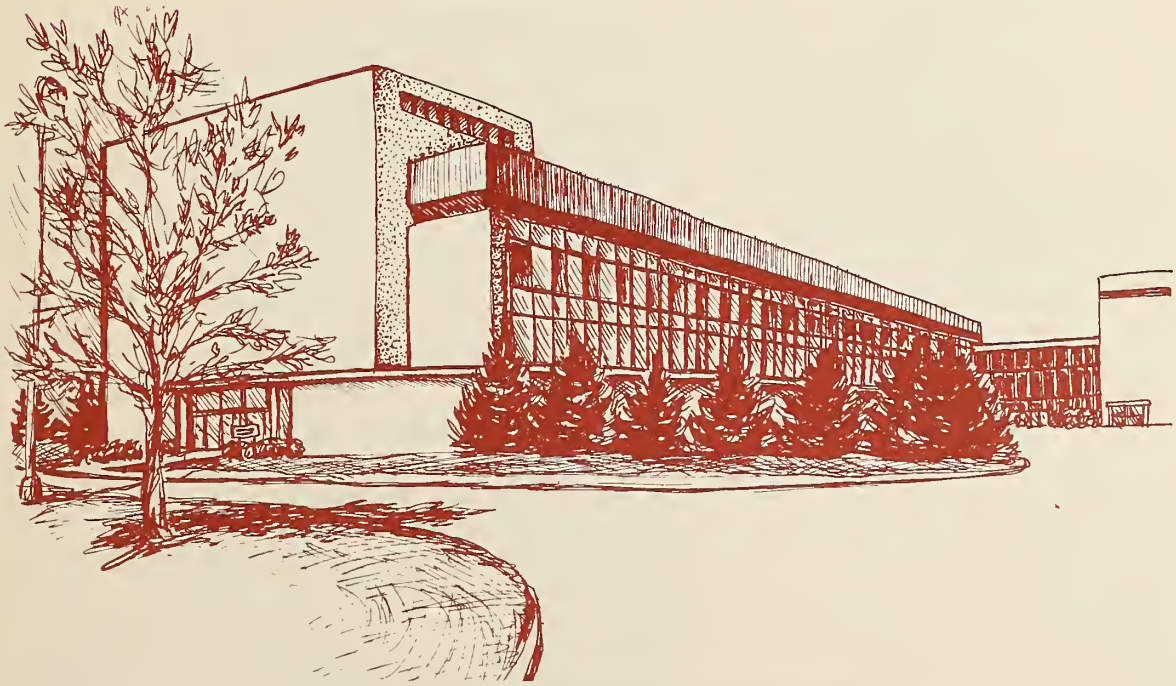
What is the Center?

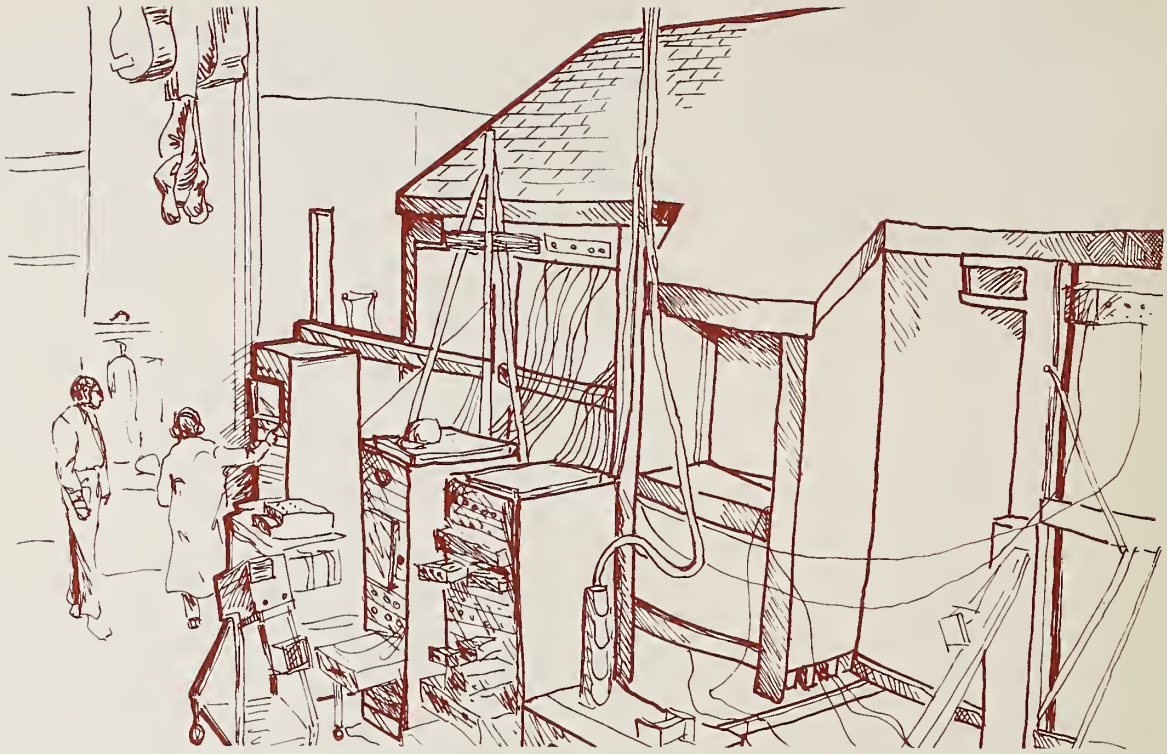
What is the Center for Building Technology? Simply stated, the answer is *people*, working in a comprehensive building research laboratory. Approximately 250 staff members bring their individual talents and professional disciplines together for three reasons: (1) to advance building technology by providing technical and scientific bases for criteria and standards that improve the usefulness, safety, and economy of buildings; (2) to foster the use of improved technology in all sectors of the building community; and (3) to improve energy conservation in buildings, communities, and industry.

These are complex building objectives. To deal with them, the Center operates in an interdisciplinary fashion. Researchers from over 30 disciplines — from mechanical and civil engineers to chemists, architects, economists, and psychologists — work together in developing a measurement base for performance criteria and for applying new building technologies, techniques, and materials.

To visualize this interdisciplinary concept, consider the single topic of windows. The Center has studied them from many viewpoints: How do they affect the design of a building? How do they affect light? How do they affect people? How do they transmit heat? How secure are they from burglars? How are they related to our sense of privacy? In this project, as in the Center's other projects, guidelines and criteria are developed to improve building practices.



The Center for Building Technology, part of the NBS campus at Gaithersburg, Maryland. Its 6,500 m² (69,500 ft²) includes office space, as well as the Center's unique and specialized laboratories.



The Center's work contributes to upgrading building codes, specifications, standards, test methods, guidelines, and design criteria to better meet the needs of occupants. What it strives for are *performance criteria* — which are much more relevant to the user than *prescriptive criteria*. Performance criteria focus on user requirements and the attributes necessary to satisfy them: they concentrate on the *effects* of a building technique or material. On the other hand, prescriptive criteria stipulate a particular way to reach that effect. Thus, performance criteria encourage creativity and economy in design and construction.

To reach its objectives, the Center has specialized laboratories and test facilities for structures, materials, and building service systems, and huge environmental chambers for evaluating the thermal performance of entire houses. The Center uses the latest in research techniques: thermography, acoustic emission, automated measurement of decay rates of tracer gases, computer-controlled data acquisition systems, and electron microscopy. The Center's business is to advance building technology — in one organization where all phases of buildings are looked at. It constantly responds with improved ways of observing, recording, analyzing, and developing improved building performance — especially important now, when demands for buildings are severe.

The Center is a unit of the Institute for Applied Technology, and the largest Center within the Bureau. It regularly draws on the experience, skills, and special laboratories of other Bureau groups.

Modular homes are investigated for their reaction to simulated natural (wind and snow) loads in one of the structural laboratories. The home is connected to an electro-hydraulic materials testing system and data acquisition system [200 channel capacity; 225,000 N (50,000 lb) maximum load].

Another aspect of the Center's impact on the building community is visible from a brief look at the construction industry and the forces that work upon it. The building industry is one of the largest in the United States — over 4 million workers. In 1974, new construction totaled more than $100 billion, of which $40 billion was spent on building materials. Maintenance and improvements to existing buildings added to the $100 billion. During the past four years, spiraling construction costs increased the price of the typical new one-family home 50 percent, exceeding substantially the overall inflation rate.

The industry supplies a market that is sensitive to a host of factors. Building codes groups across the country, building standards, Federal specifications and regulations, economic and social changes, individual and family preferences, and long-standing traditions within the industry itself, all affect the building marketplace. Added to these forces are domestic and foreign building innovations and research findings. The Center considers needs and effects of each of these sources and provides responsive technology.

The areas of the Center's research are many. For example, they range from energy studies to economics, behavioral studies, structural research, and disaster mitigation. The Center also is very much concerned with lead paint poisoning, mobile homes, and safety standards for construction. Each of these areas, and many others, are discussed in this report.

The Center's identity most clearly is seen in its accomplishments and ongoing projects, whose sponsors consider its research a necessary and practical investment. After all, it is one thing to say what the Center is; it is quite another to let the work speak for itself — as it does on the following pages.

It should be kept in mind that the studies and sponsors described here represent only a fraction of Center research. Additional information is found in companion documents: the *Project Summaries*, and the list of *CBT Publications*. The Center invites direct inquiries on completed, ongoing, and proposed new research projects.

Disciplines

Architect
Architectural Engineer
Behavioral Psychologist
Bioacoustician
Ceramic Engineer
Chemical Engineer
Chemist
Civil Engineer
Code Analyst
Communications Specialist
Cost Engineer
Economist
Electronics Engineer
Environmental Engineer
General Engineer
Geologist
Housing Technologist
Hydraulics Engineer
Industrial Engineer
Materials Engineer
Materials Scientist
Mathematician
Mechanical Engineer
Metallurgist
Operations Research Analyst
Physical Scientist
Physicist
Psychologist
Public Administrator
Quality Control Specialist
Safety Engineer
Sanitary Engineer
Sociologist
Standards Engineer
Structural Engineer
Urban Planner

Energy Conservation

If there is one topic that crosses all organizational lines at the Center, it is Energy Conservation — a national problem that the Center has been concerned with for some time. Research is being performed under the sponsorship of the Federal Energy Administration, the Energy Research & Development Administration, the Department of Housing & Urban Development, Department of Defense, General Services Administration, Department of Commerce, and the National Science Foundation.

One-third of all energy consumption in the United States takes place within commercial and residential buildings. About 40% of this energy could be saved. To help solve this problem, the Center studies the thermal performance of the building enclosure and its heating, ventilating, and air-conditioning systems. The Center measures total demands for energy in buildings. It evaluates the effects of temperature, humidity, and odors on human health, productivity, and comfort. This knowledge guides regulatory authorities in protecting the health of the public and in effectively allocating energy resources. Research guides designers in providing useful yet significantly more energy efficient buildings. Examination of energy use assists owners and occupants of existing buildings to better select cost-effective, energy conserving improvements in buildings, equipment, and operating practices.

The Center is studying new strategies for waste heat management in industry, involving case studies, equipment options, and financial and taxation analyses. The Center's manual of energy conservation techniques for industry has been widely used and has been the basis of a number of university courses in engineering for energy savings. The Center's next step is to turn to combustion technology for improved use of process fuel in factories. This work is expected to involve infrared thermography and laser scanners, as well as criteria for furnace designs to permit combustion of shredded wastes.

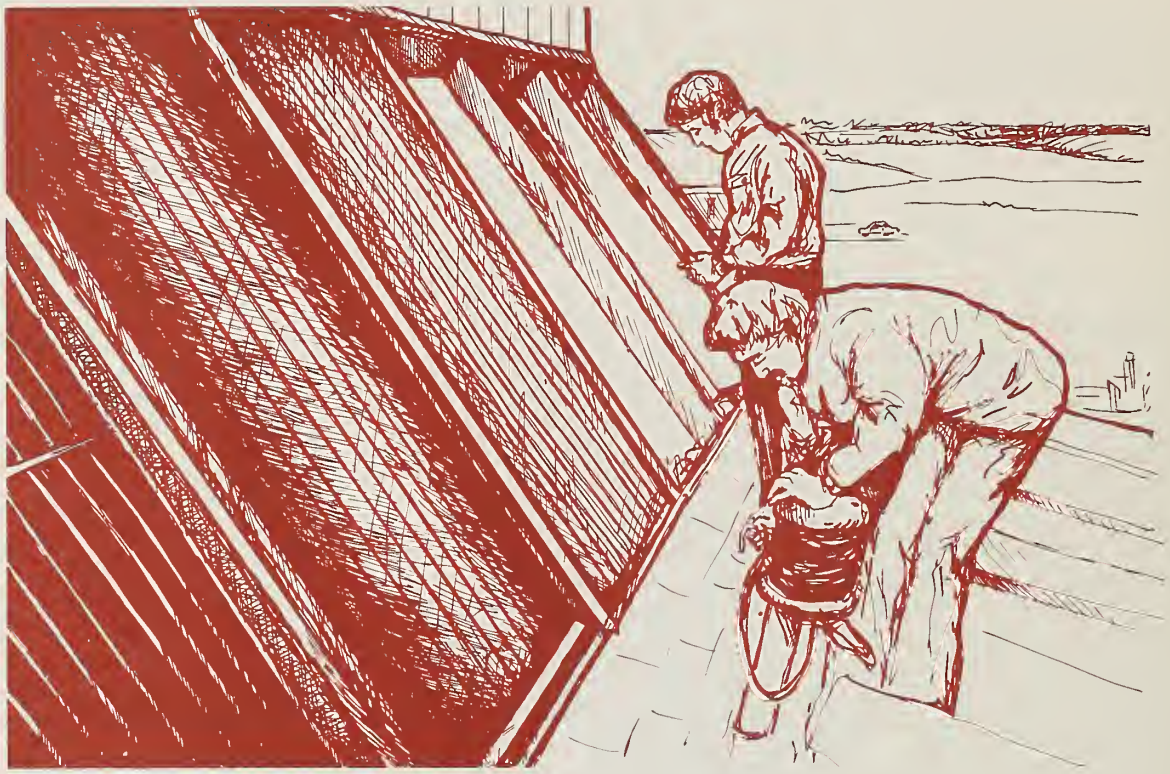
In 1973, the Center was asked by the National Conference of States on Building Codes and Standards to develop design and evaluation criteria for energy conservation in new buildings. The criteria were used by the American Society for Heating, Refrigeration, and Air Conditioning Engineers, as the basis for a national voluntary standard on energy conservation in new buildings. This standard — covering the energy performance of the design, the envelope, the heating, ventilating, and air conditioning system, the water and service network, the lighting and electrical distribution system — may be adopted in State and local building codes and in standards for Federal buildings.

Communities are the third thrust of energy conservation work. For the Modular Integrated Utilities System (MIUS), a Department of Housing and Urban Development project, the Center is evaluating the patterns of energy and water use and waste disposal in the total energy demonstration project at Jersey City, New Jersey. By instrumentating and evaluating the performance of that project, a basis is gained for performance standards for future MIUS systems.

In cooperation with Princeton University and sponsored by the National Science Foundation, energy use is being studied in a modern community of 1000 townhouses and 150 single-family houses. Surveys, thermographs, and tracer-gas decay rates are being used for an accurate portrait of energy use. The Center will be involved in further studies of district heating techniques, having already well established the knowledge of through-the-ground heat loss in underground piping. These techniques will help improve our national energy stance — especially when you consider that 20 percent of our present energy is used for space heating in buildings and homes.

The Center has developed a sophisticated computer program for energy use analyses called the NBSLD (Load Determination) Program. It treats some 300 variables in three categories: the weather, the building, and the way the building is operated. The computer output is presented in the form of a profile of heating and cooling loads on an hourly, daily, weekly, monthly, or yearly basis. The NBSLD program has been vital to the design of buildings that use solar energy. The program has been used, for example, to evaluate proposed school designs for the New York City Board of Education and has been made available to more than 110 other users, including the General Services Administration for the design of a new Federal office building in New Hampshire. Similarly, the Center has assisted in the energy analyses of NBS buildings at Gaithersburg. These have contributed to reduced demands for light and chilled air and to installation of more efficient ventilation.

Solar collector panels are being installed on the roof of a commercially available, factory-built townhouse erected on the NBS campus. This system, using the sun's energy for space heating and cooling and warming water, will aid in development of test methods and standards for solar energy products.



Solar Energy

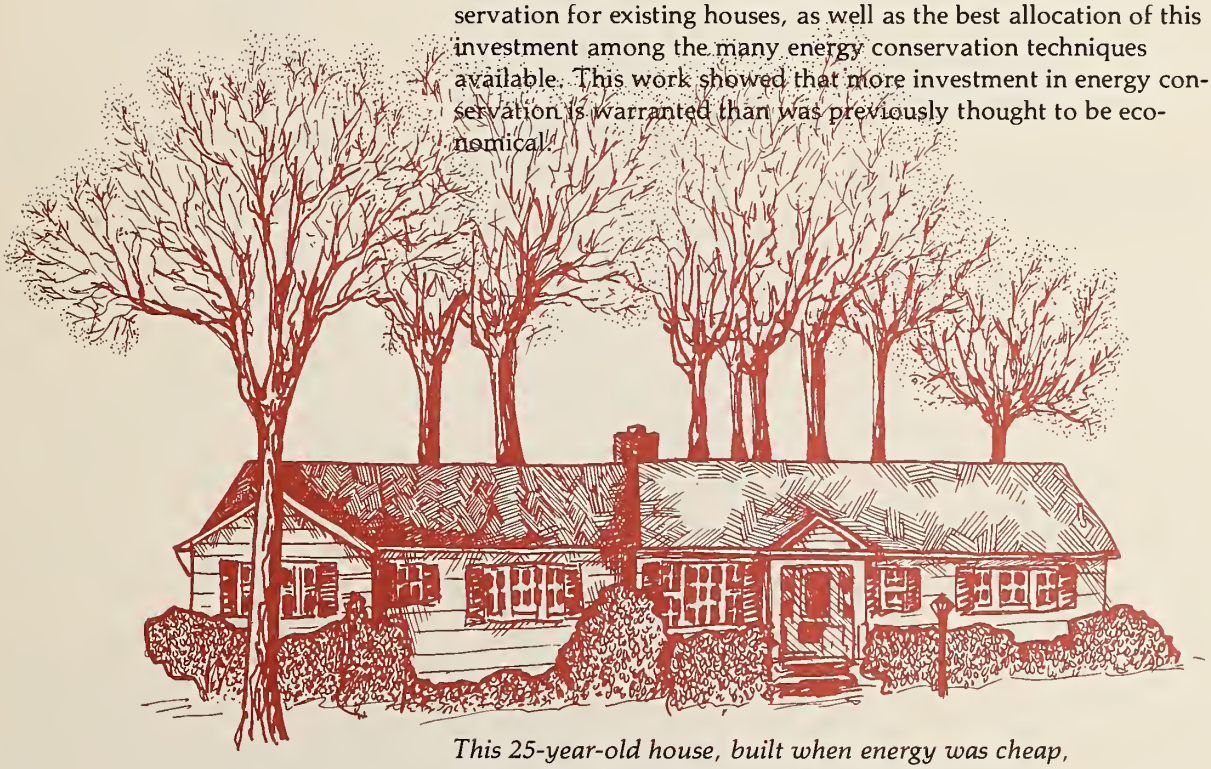
The Center is developing performance criteria and interim standards for solar heating and cooling systems and is directly involved in the evaluation of critical components and systems. The criteria and standards will be used by the Department of Housing and Urban Development in a residential demonstration program as well as in their loan insurance programs. In work for the Energy Research and Development Administration, the Center has developed test methods for solar collectors and thermal storage devices. These test methods are being developed into national standards through the American Society of Heating, Refrigeration, and Air Conditioning Engineers.

A townhouse on the NBS grounds at Gaithersburg is equipped with a solar heating, cooling, and hot water system for the study of test and evaluation methods. Beginning in the summer of 1976, the Center will be assisting the General Services Administration in the evaluation of a solar heated and cooled Federal office building located in Manchester, New Hampshire.

Economics

Building Economics receives special attention at the Center. Is there, for example, a rational way of deciding whether to abandon or to rehabilitate a building? There are many factors that affect this decision, one that is vital to landlords, tenants, and municipalities, as well as to the Department of Housing and Urban Development. Major community investments are made in water treatment plants. Under current Federal cost-sharing rules, cities may opt for water treatment facilities that are low-cost to them, but that are very costly when looked at from society's viewpoint. These cost-sharing regulations have been studied for the Environmental Protection Agency to help it prepare new regulations for more efficient programs for cleaner water. The Center also has looked into the costs of natural disasters, such as floods, hurricanes, and tornadoes. The economics of protection against progressive collapse in new buildings has been studied to determine the benefits and costs resulting from the investments of builders and owners in safety. Designers have been provided guidelines on how to evaluate building life-cycle costs for more efficient future investments in planning, designing, constructing, and using buildings.

Economists and operations researchers also have applied microeconomic and mathematical tools with thermal engineering principles in a number of evaluations of alternative energy conservation techniques. The Center developed a methodology for determining the economically optimal investment level in energy conservation for existing houses, as well as the best allocation of this investment among the many energy conservation techniques available. This work showed that more investment in energy conservation is warranted than was previously thought to be economical.



This 25-year-old house, built when energy was cheap, has been retrofitted with energy saving devices and heat-retaining techniques in order to measure their effectiveness.

At what point do environmental noise or lighting problems begin to interfere with normal everyday functioning?

Sensory Environment

What levels of light do people need for performing various tasks? How much noise can you tolerate before it disrupts your concentration? What size, shape, shading, and glass tint are preferable for window design? What kinds of colors should be used for emergency warnings? The answers to these all impinge on building design. In fact, the answers on light levels and windows have a major effect on energy conservation. In response, the Center has developed a cathode-ray tube system to measure effects of illumination levels on human performance of tasks approximating those in normal life. In another study, it addressed the psychological reaction to environments with and without windows and the impact in designing energy-efficient buildings.

Similarly, the Center is investigating how humans behave during fires. It found, for example, that our behavior is quite rational. As a result, fire emergency actions can be made more effective, by being made more specific: people safely above or below the fire in tall buildings should perhaps be asked to stay where they are to avoid jamming escape routes.

Effective building research is *people* oriented. It studies individual needs for light in determining appropriate illumination levels; deals with people's response to noises to form a rational basis for acoustical criteria for buildings. This relating of human behavior to physical conditions is typical of research at the Center. After all, most buildings are intended to support human activity, not just as monuments.

Architectural Research

How do people use stairways? This question is significant: Stairs are involved in more accidents in this country than any other product (except automobiles and bicycles). For the Consumer Product Safety Commission, the Center has studied stairways in schools, homes for the aged, and airports to uncover the causes of accidents. Among other matters, it wants to know why people cross over from handrail to handrail on wide stairs. It also wants to know how lighting affects our depth perception, especially in halls and stairs. The Center also is surveying user satisfaction with new housing, in a project sponsored by the Department of Housing and Urban Development. Ultimately, this research will result in improved design criteria for safer, more accomodating buildings.

Visual separation and acoustical isolation are other areas of research. Essentially they seek to uncover how building and room design — as well as partition placement within a room — affect one's control of his environment and can lead to more efficient use of land and space.

Here, a researcher videotapes the way typical users negotiate an architecturally pleasing, but possibly hazardous, stairway. Other research dealing with stairs focusses on lighting levels, tread type, railings, and the stair design itself (ratio of step run to rise). Similar research in numerous locations across the country is expected to lead to new stair design criteria.

Mobile Homes

Millions of Americans live in mobile homes. But are they a good investment? Are they safe? How do they compare with conventional houses? The Center is developing criteria to improve the safety and usefulness of mobile homes. In research sponsored by the Department of Housing and Urban Development and the Federal Energy Administration, the Center has tested the thermal characteristics of such housing in its environmental chambers. It analyzed their heating systems and also studied the performance of 3,000 emergency housing units set up by the Department of Housing and Urban Development in 1972 for the Hurricane Agnes victims. Recommendations were developed for preparing mobile homes for long term storage until needed in the event of a future disaster. The Center took part in the revision of the American National Standards Institute (ANSI) standard for mobile homes, covering subjects of fire protection, durability, and electrical and plumbing performance. This standard was used as the basis for the National Standard on mobile homes promulgated by the Department of Housing and Urban Development under the Housing and Community Development Act of 1974 (P.L. 93-383). The Center, sponsored by the Department of Housing and Urban Development, is also looking at mobile homes' resistance to wind forces and the extent to which the national standards for mobile home construction (the ANSI standard) have been used — or deviated from — by state regulatory agencies.

An aerial view of mobile homes. Are they safe? The Center's investigations — like the evaluation of these homes in Pennsylvania, erected by HUD after Hurricane Agnes — are finding out.

Security

For the Justice Department's Law Enforcement Standards Laboratory, the Center has studied the resistance of locks, doors, and windows to burglars. Human subjects were used to determine the amounts and types of pressures they apply; and standardized tests were based on the forces induced in security devices. The tests, in turn, can be used to compare classes of doors and locks. The research covered sliding-glass doors, wooden and steel frames, and locks — including those liable to forced entry by celluloid and other thin strips. The outcome of these studies was the development of performance criteria for security systems as an aid both to consumers and law enforcement officers.

How secure is your door? The Center is attempting to determine criteria for doors and locks.

This study of a pressing national health and housing problem illustrates how the scientific resources in other NBS units support work at the Center.

The Center, sponsored by the Department of Housing and Urban Development, is working with the building materials industry to identify and develop new techniques for eliminating lead paint hazards in housing. In joint efforts with the Applied Mathematics Division, estimates of the magnitude of the lead poisoning problem were made and statistical surveys of housing and children were designed and implemented. The Analytical Chemistry Division has assisted the Center by evaluating lead paint detection devices and providing standards of lead in blood for determining the proficiency of chemical laboratories that make those measurements.

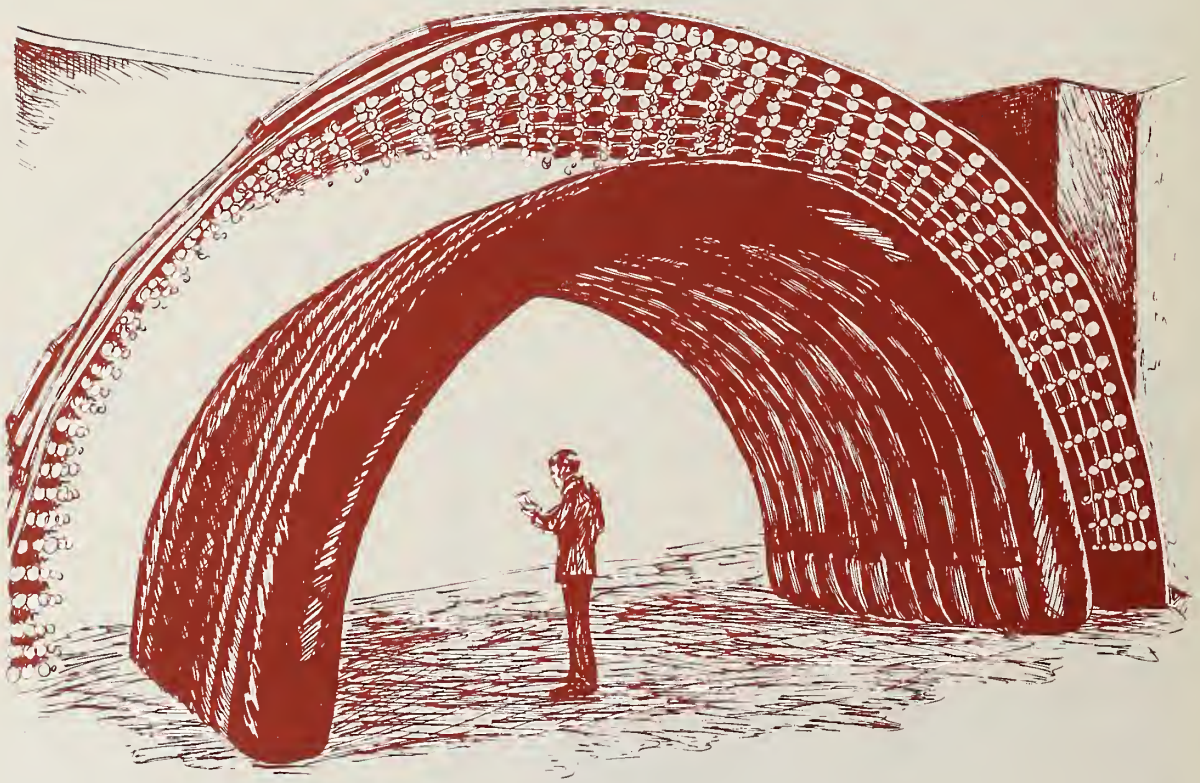
The Center is establishing a lead poisoning information clearinghouse which will make research results and other important findings available to health, housing, and code enforcement officials as well as government agencies and the general public.

Lead Paint Studies

Peel, but don't eat! The Center is the focus of this important research within NBS.

Thermal Studies

This inflatable structure was found to have delamination problems at high temperatures. Here, it is tested in one of the Environmental Chambers. The chamber was kept at 38°C (100°F), while the surface of the structure was maintained at 93°C (200°F) to simulate natural exposure for the test. This research was a key to defining durability requirements.



Substantial relief from the energy crisis can be achieved by using energy more efficiently in existing buildings. The Center has retro-fitted a 25-year-old house — built when energy was plentiful and cheap — with a series of energy-conservation techniques: caulking, various insulations, storm windows, and a heat pump. It has studied the efficiency of those improvements, and also the entrapment of moisture in the newly insulated walls and ceilings. This research, sponsored by the Federal Energy Administration and NBS, provides a firm basis for the recommendations in the consumer guide "Making the Most of Your Energy Dollars in Home and Heating and Cooling."

Similarly, the Center has studied, for the Department of Housing and Urban Development, the heat gain and heat loss of a masonry house and a wood-frame townhouse in its environmental chamber to test, improve, and verify techniques for predicting thermal performance.

The Center developed an improved reference standard apparatus for thermal conductivity measurements for building insulation. New instruments are being developed to measure the physical parameters affecting thermal comfort in buildings.

With the General Services Administration and the Energy Research and Development Administration, the Center is engaged in the field studies on the energy conservation performance of a 7-story office building in Manchester, New Hampshire. Its computer program for thermal performance, called NBSLD, was used to assess energy use in alternative designs. The building, which will have a 437 m^2 (4,700 ft^2) solar collector, will be studied closely for the effects of its thermal performance on the people who work there. It is expected that this activity will provide improved guidelines for designing future office buildings.

In patterns like these, infrared thermography indicates the areas of high heat loss from a typical dwelling, constructed for test purposes on the NBS grounds.

Materials

Materials research at the Center is interdisciplinary, employing the talents of researchers in the fields of materials science, chemistry, physics, and metallurgy. Together, the materials team has developed new ways of solving problems of materials performance and durability.

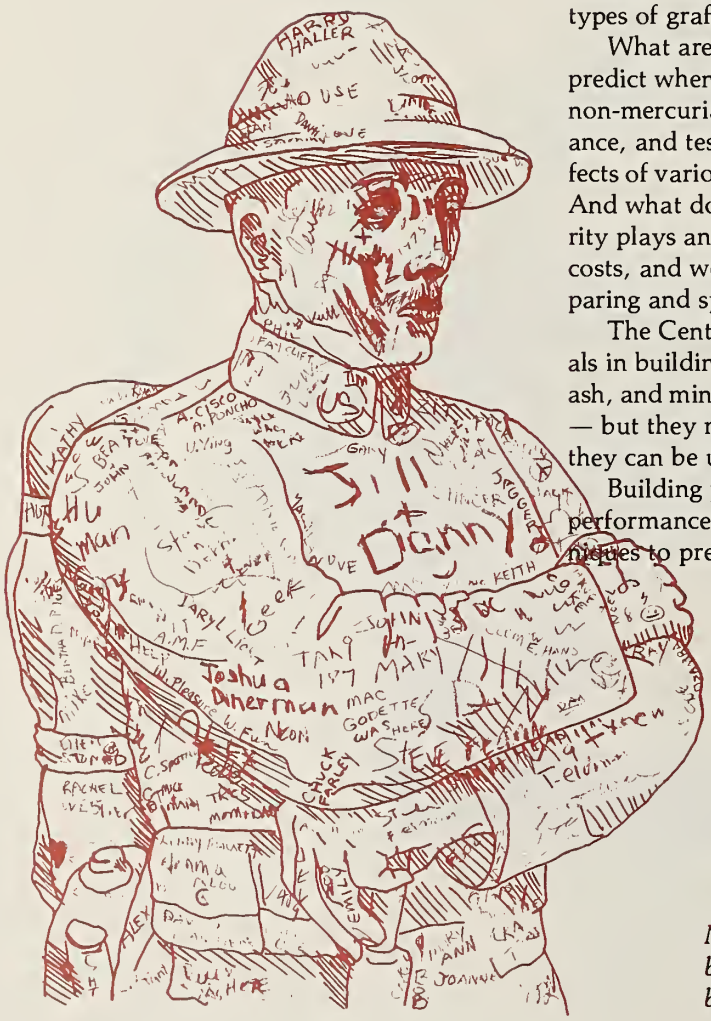
The $3 billion each year that the country spends on built-up roofing offers a significant area for savings if roof life can be prolonged and failures can be avoided. Among other capabilities, the Center developed a hail gun to simulate the effects of hailstones on roofing. The Center has also developed test methods for the flow properties of roofing asphalt. The performance of energy conserving roofing systems and non-destructive testing of moisture within roofs, are other important areas the Center is investigating.

Each year graffiti removal costs taxpayers millions of dollars — $2 million in New York City alone last year. With sponsorship of the Department of Housing and Urban Development, the Center has responded to this need by developing performance specifications for two types of materials: those to remove the contributions of these artists of the streets; and those to prevent various types of graffiti from adhering in the first place.

What are the mechanical properties of paints? How can we predict when they will tend to crack and chip? Paints containing non-mercurial fungicide have been tested to assess their performance, and test methods have been developed to evaluate the effects of various quantities of chromium (a health hazard in paints). And what do we know about building joint sealants? Their integrity plays an important role in energy conservation, maintenance costs, and weather damage. The Center is studying ways of comparing and specifying the characteristics of such sealants.

The Center also is playing a role in the use of recycled materials in building construction. Waste glass, blast furnace slag, fly ash, and mining wastes all might have a place in today's materials — but they must be evaluated and standards must be set before they can be used with confidence by designers and engineers.

Building panel adhesives, improved connectors for wires, the performance of aluminum wiring, and the effectiveness of techniques to preserve historic buildings are other studies underway.

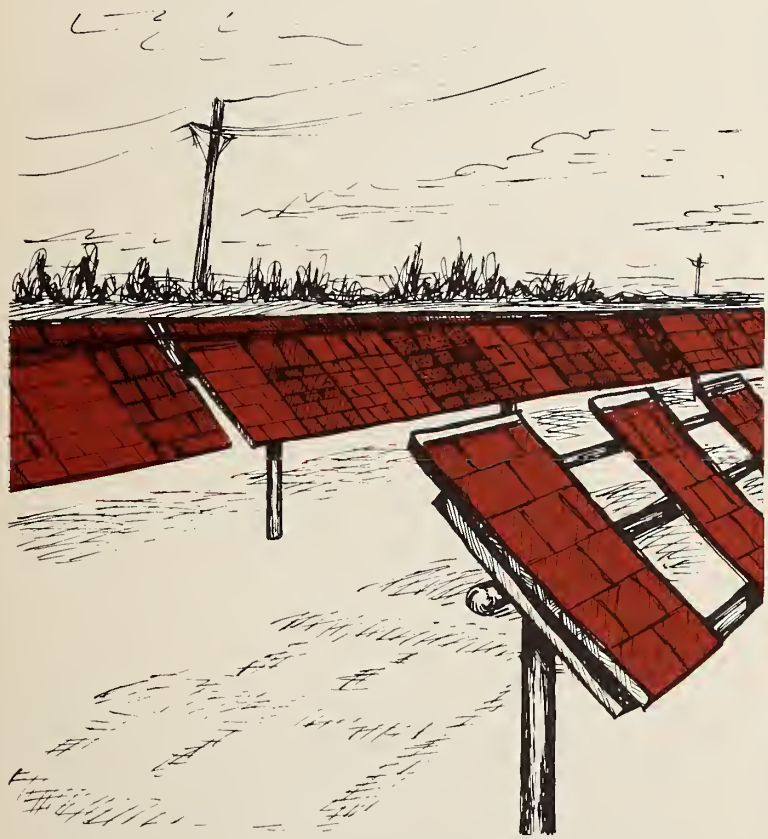


Materials research at the Center is aimed at making buildings and other structures easier to clean up — or by reducing the adhesion of graffiti in the first place.

Durability

How often do buildings — or their components — need replacing? Is it possible to predict the useful life of a building? What about the useful life of an element of a building, such as its plumbing system? The Center seeks to make such predictions possible, to help the nation make the best use of its building resources. Standards and uniform measurement techniques are required to evaluate everything that goes into a building — from the coatings that protect it, to its internal service and structural systems.

Among the Center's facilities are its accelerated weathering devices. These measure the rates of decay under many combinations of degenerative conditions — ultraviolet radiation, moisture, ozone, sulphur dioxide, salt spray, and heat, to name but a few. To complement the accelerated weathering equipment, the Center also operates natural weathering facilities at eight outside sites, from Puerto Rico to Alaska.



Here, various samples of material — roofing, paints, sealants, sidings — undergo long term weathering tests.

Among the Center's special test facilities is the 5-story plumbing research test tower. This tower is used to study the performance of plumbing systems and components and is equipped with an automated hydraulic load controller and action display system. The equipment permits preprogramming of test loads and its display board can be wired directly to the plumbing components under test. It displays failure points and other operational characteristics within the system. Researchers can then adjust experiments to determine the parameters for optimal performance of the system. Test data are fed into a small computer compatible with the NBS central computer.

Research is continuing on reduced-size vents. Although these smaller vents have obvious economizing value (they use less material), most plumbing codes do not authorize their use. A field study in new home construction is underway for the Department of Defense, and further research for the Veterans Administration considers the use of smaller vents in tall buildings. These data will be used by the consensus standards groups to develop improved standards for incorporation in plumbing codes.

The Center developed hydraulic performance criteria and submitted recommendations to the American National Standards Institute committee and other standards groups for a performance-based standard under development for the National Plumbing Code. In addition, a 5-story single-stack drain-waste-vent system was studied in use to obtain performance data.

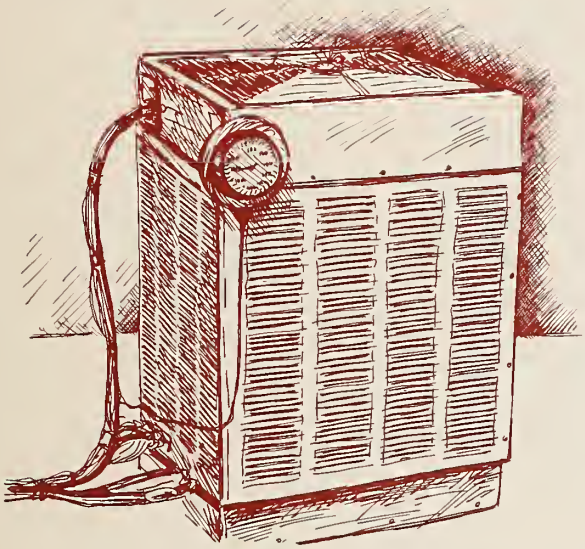
The Center has made performance tests and developed performance criteria for plastic pipes and their connections, and vacuum drainage systems. Recently it sponsored a Roundtable with *American Home* Magazine on, "What Consumers Should Know About Water Conservation and Costs."

Plumbing & Drainage

The plumbing test tower can be adjusted to test plumbing systems and components up to seven stories. Its recirculating water supply provides pressures up to 550 k Pa (80 psi). Its output is as high as 3800 liters (1000 gallons) per minute. Constant predetermined pressures can be controlled to within 7 k Pa (1 psi). The tower is equipped with a data acquisition system with a capacity of 256 channels.

Mechanical Systems

This heat pump is undergoing tests to measure its energy efficiency.



Effective equipment selection and energy conservation decisions require knowledge of the seasonal performance of equipment as actually used in service — to relate that use to costs, energy consumption, and efficiency. The Center is developing dynamic test procedures to define this performance for heat pumps, heating and cooling systems, and other equipment. The Center also is studying the effect of partial loads on boiler efficiency and has made laboratory tests of modular gas-fired boilers. Information was developed on the increased seasonal efficiency from use of modular gas-fired boiler systems in the heating of buildings. This is intended to be used in the development of new consensus standards for testing and rating equipment at part-load operation. Similar studies in both the field and laboratory are underway for heat pumps and oil furnaces.

The Center developed measures of household refrigerator and freezer performance to encourage consumers to purchase more energy conserving appliances — and manufacturers to make more efficient appliances — through the NBS energy labeling program. This program is being carried out at several field sites and a laboratory simulation system is under development.

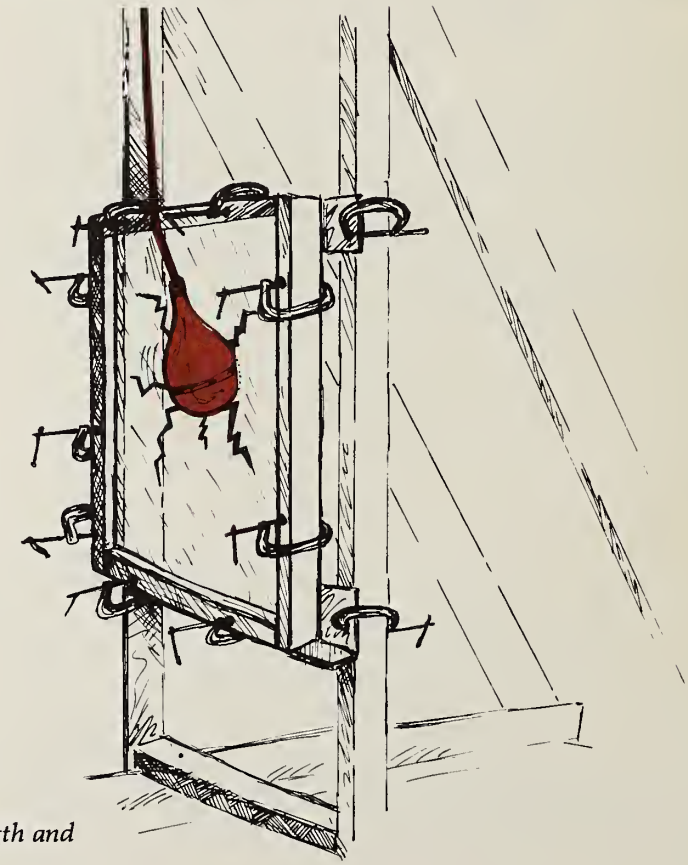
The comparative energy efficiency and environmental control provided by the commonly used types of central heating and air conditioning systems are being evaluated for large buildings. Is the day approaching when products as large as whole buildings will be labeled for energy efficiency? These test methods are prerequisite.

Safety

What is a slippery floor? The Center is engaged in measuring slipperiness and has designed and constructed a portable slip tester — to be used on floors, stairs, bathtubs, and swimming pools. This device is under consideration by the American Society for Testing Materials for use in a standard for measuring the slip-resistance of bathtub surfaces.

How strong should shoring members be during construction? What should the design criteria be for guard rails and worker-resistant systems around the roofs and floors of multi-story buildings and other work sites? For the Occupational Safety and Health Administration, the Center is studying these factors. It has completed research on non-destructive tests to determine concrete strength during construction to allow safe removal of formwork. The answers are important to the State's codes and standards officials, to the Occupational Safety and Health Administration, and to the construction industry as a whole.

Architectural glass is involved in some half-million injuries each year. The Center, in support of the Consumer Product Safety Commission, is evaluating test methods and criteria used in standards for such glass products, to thus create a safer environment.



Architectural glass is evaluated for strength and shatter characteristics in the laboratory.

Disaster Mitigation

Early in 1971, California's San Fernando Valley was hit by a costly — both in lives and property damage — earthquake. Engineers from the Center were among the first on the scene. Often, a Center team is requested to assess building damages and the remaining threat after a disaster and to study what are real tests of real buildings. Two Center engineers were on the first structural research team to reach Managua, Nicaragua, after its 1972 earthquake. The Center has been asked to give similar technical assistance after other disasters: the Alaska flood, Hurricane Camille, the Lubbock Tornado, Hurricane Agnes, the St. Louis Federal Records Center fire, and the Fairfax, Virginia highrise building collapse. Based on these field experiences and laboratory research under sponsorship of the Defense Civil Preparedness Agency, the Center developed a methodology for surveying and evaluating existing buildings for their resistance to natural hazards.

But what of buildings now underway or soon to be constructed? For example, the largest earthquakes in U.S. history struck near New Madrid, Missouri, in 1811-1812. If they were to recur today, property damage losses could well total over $50 billion, with massive human suffering and many lives lost. Against this

This damage was sustained during the 1971 San Fernando earthquake. Center research, including post-disaster surveys, is aimed at minimizing such property losses, human suffering, and expenditure for disaster relief in future quakes.

threat, the Center, sponsored by the National Science Foundation, is developing improved seismic design provisions. Among basic factors covered are:

- Architectural, structural, mechanical, and electrical features of construction related to minimizing seismic damages.
- Seismic, geological, and soil-site effects on design loads.
- Soil-structure interaction.
- Analysis and standardization of structural loading and resistance criteria.

The work of this project is being carried out by approximately 100 professionals from across the U.S.: architects, engineers, geologists, university researchers and representatives from the regulatory system. The Center is working with the Applied Technology Council, a non-profit organization established by the Structural Engineers Association of California, which represents 2,000 members and is serving as a liaison with associations in many states, including Washington, Oregon, Nevada, Utah, Hawaii, and Illinois. Other important inputs to this study are from state and municipal building officials, representatives from the Federal government, and university researchers.

This program on building practices for disaster mitigation provides the technical base for improved criteria and standards leading to better performance of buildings subjected to natural hazards. The Center participates with other Federal agencies and with other groups of the building community to promote compatibility and to reduce duplication in Federal disaster mitigation programs.

Here, the connection between two prestressed concrete columns is being loaded in a 2,700,000 N (600,000 lb) compression test machine.

Structural test facilities include five other specialized testing machines for measuring the characteristics and performance of building components and materials.

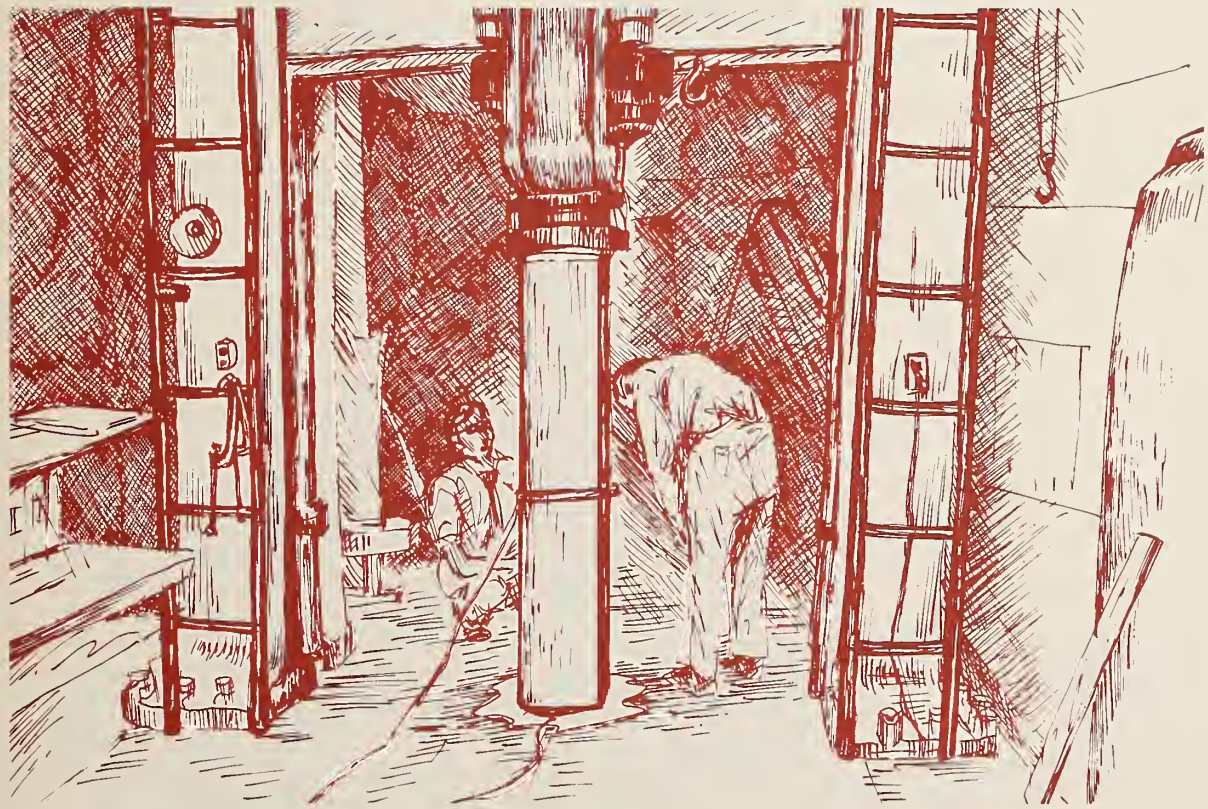
The laboratory is constructed with a heavily reinforced tie-down floor, permitting mounting of complete structural members. Hydraulic actuators provide test loads in static tests while closed-loop electro-hydraulic actuators provide test loads in dynamic tests. Automatic recording of up to 200 channels of sensor data is accomplished by a minicomputer-controlled data acquisition system.

Structural Studies

The phenomenon known as progressive collapse (extensive damage resulting from a localized initial failure) has received substantial attention. For the Department of Housing and Urban Development, the Center has studied many modes of building collapse, and the probabilities of their causes, such as gas explosions or the removal of structural support by, say, a runaway truck. The results of this research will identify those building types more susceptible to progressive collapse — as well as strategies for avoiding it. A ¼-scale model of a parking garage (post-tensioned unbonded flat-plate construction) has been loaded to failure to verify modeling techniques for predicting the susceptibility of structural systems to progressive collapse.

The properties of unreinforced masonry walls have been studied to better define their resistance — for example, to increase safety in earthquakes.

The Center has measured the forces and effects of wind on buildings at sites around the world. The findings are used to verify analytical techniques and wind-tunnel modeling for improved design criteria. The Center recently was asked by the Australian government to review plans for rebuilding Darwin after its Christmas Eve hurricane of 1974. It also is calculating the speeds that various pieces of debris are likely to attain during tornadoes. The object of this research, for the Nuclear Regulatory Commission, is to develop improved design criteria for nuclear power plants.



International Programs

The Center's work also is useful in other countries. It shares abroad the latest in our building technology, and brings the best of foreign research to our shores. To these ends, the Center has established ties with the following building research groups:

Building and Road Research Institute, Ghana
Building Research Association, New Zealand
Building Research Establishment, United Kingdom
Building Research Institute, Japan
Central Building Research Institute, India
Danish Building Research Institute
Division of Building Research, Australia
Division of Building Research, Canada
Institute for Research Technology, Brazil
National Building Research Institute, South Africa
National Swedish Institute for Building Research
Norwegian Building Research Institute
Scientific and Technical Building Center, France

The affiliations with these groups take many forms. They range from joint-cooperative programs and information exchange to the sponsorship of various forums for the presentation of building research. To name but a few projects: optical deflection instruments used in the Post Office tower in London; studies of vacuum drainage technology with the Israeli government — a nation where water is at a premium; with Russia, as a result of a U.S. and USSR agreement, a number of exchanges — recently a seminar on seismic considerations in housing design, which was held at the site of the 1966 Tashkent earthquake. The Center provides advice to developing countries as well. A center team has been studying the building industry of Egypt, with special emphasis on equipment, materials — how to build concrete plants, for example — and construction methods. With the State of Sao Paulo, Brazil, through their Institute of Research Technology, the Center is training one of their staff toward improving the Institute's building research capability.

The Center also has undertaken a worldwide study to develop improved design criteria for the wind resistance of low-rise buildings in developing countries. The work is centered in Jamaica, Bangladesh, and the Philippines. A number of Philippine buildings have been instrumented with pressure-transducers on the roof and walls; data are collected on magnetic tape. The results will include a significant improvement in our knowledge of extreme wind loads on low-rise buildings, an improvement in building design criteria to better resist those winds, improved wind-risk maps, better use of timber and masonry fasteners, and a socio-economic analysis of the local building needs.

The Center's studies of wind effects on structures are worldwide. Here, London's GPO tower, which dominates that city's skyline and which is being studied with Center equipment, is overlaid with the Center's Philippine and USA based work, which investigates the effects of extreme winds on low-rise structures.

Codes & Standards

With the exception of Federally owned buildings, the responsibility for building regulations is reserved to the States. The States have largely delegated their authority to the local governments. At present there are over 12,000 code administering jurisdictions in the United States. The practices of these jurisdictions often have evolved from local experiences. As a result, regulations and procedures across the United States vary widely in the way in which the health and safety of building occupants are protected. These variations increase the costs of designing and constructing buildings, and of manufacturing building products. This forces occupants to pay more for buildings.

No matter how pathbreaking the Center's research, if that knowledge is not imparted to the nation's system of building codes and standards, the work is not complete. After all, the Center has no regulatory powers. Instead, it provides technical advice to the Federal agencies, states, and local governments, and to voluntary standards groups. It also has membership in over 200 technical committees of nationally recognized standards organizations, and participates in numerous Federal agency building groups.

This assistance has been expressed or implied in all the work discussed so far. For example, it supports the American National Standards Institute in studies of loads on structures — both in predicting everyday loads and in developing ultimate load factors to assure low risks of collapse.

New building designs and products are constantly appearing in the market. But they cannot be used until they are accepted by local code authorities. For plastic pipe, to cite but one instance, the Center has developed performance criteria to contribute toward revision of the national plumbing standards.

The Center also serves as Secretariat to the National Conference of States on Building Codes and Standards. The Conference is a forum for State and local governments, industry, and other interested parties to discuss issues bearing on building regulations — interstate reciprocity on new-product approvals, for instance — and for encouraging research on unanswered technical regulatory questions.

The Center also is working on metrication and dimensional coordination in the building industry. It works with the American National Metric Council, Conference of American Building Officials, the National Conference of States on Building Codes and Standards, the Association of Major City Building Officials, the American Institute of Architects, the National Research Council of Canada, American National Standards Institute, and the American Society for Testing and Materials.

This gun is used to simulate the effect of hail. It fires ice spheres at roofing and siding materials for testing.

Sponsors

The work of the Center is an integral part of the programs of the Institute for Applied Technology. A number of the activities cited are conducted in and with the support of other Institute units:

- Electronic Technology Division
- Center for Consumer Product Technology
- Standards Application and Analysis Division
- Center for Fire Research
- Office of Energy-Related Inventions

The Center's programs are funded by direct Congressional appropriations through the Department of Commerce and the National Bureau of Standards, and by other Federal agencies who use the Bureau's unique laboratory resources in support of their building programs.

Agency for International Development
Air Force Civil Engineering Center
Air Force Systems Command
American Hot Dipped Galvanizers Association
American Society for Testing and Materials
Army Natick Development Center
Brick Institute of America
Consumer Product Safety Commission
Defense Civil Preparedness Agency
Defense Nuclear Agency
Department of Commerce,
National Bureau of Standards
Department of Health, Education and Welfare
Department of Housing & Urban Development
Department of State
Department of Transportation
Dow Chemical Company
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Federal Energy Administration
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Maritime Administration
Masonry Institute of America
National Concrete and Masonry Association
National Park Service
National Science Foundation
Nuclear Regulatory Commission
Occupational Safety & Health Administration
Tri-Services Committee, Department of Defense
United States Postal Service
Veterans Administration

Organization

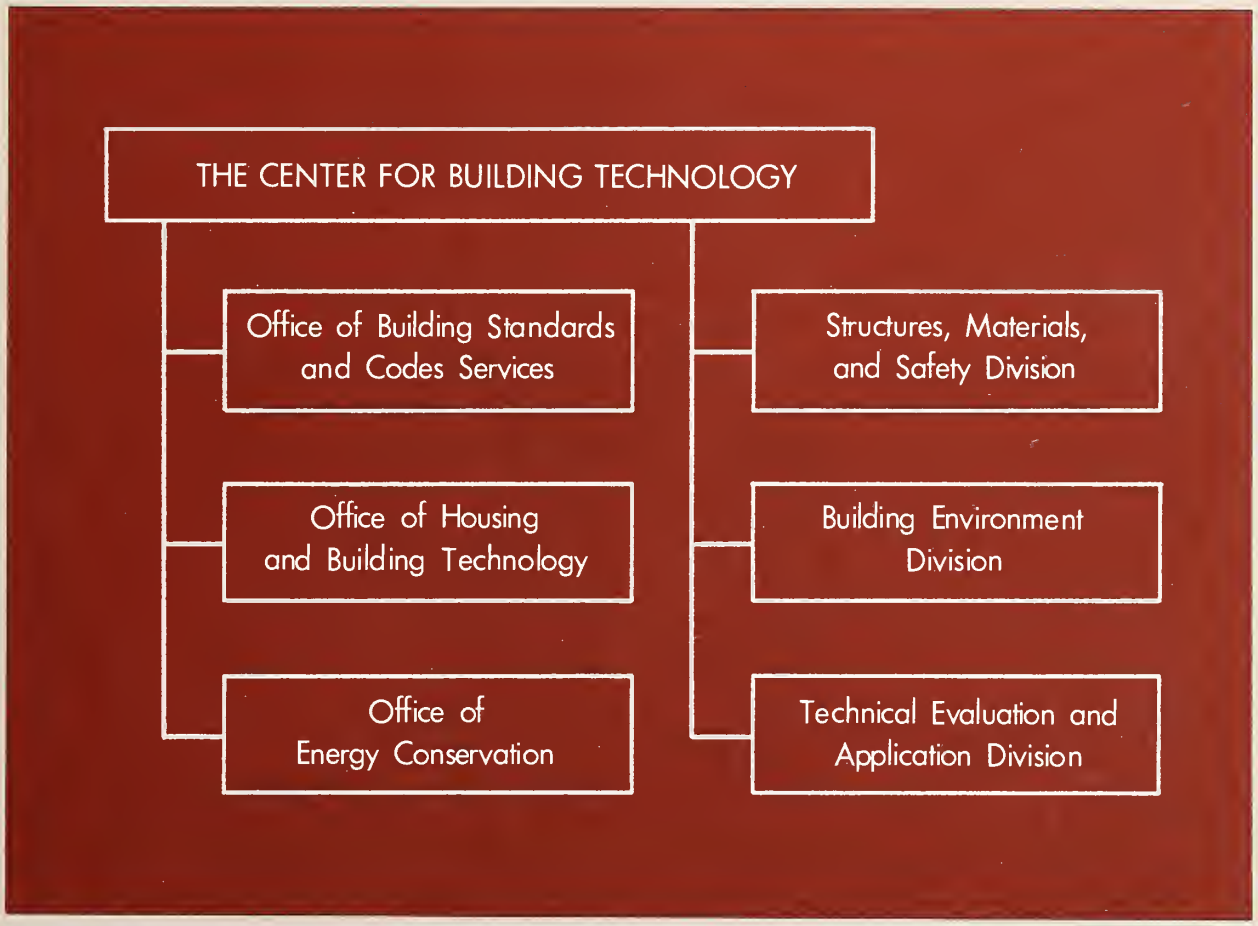
At the Center, research is carried out in three laboratory-based divisions:

- Structures, Materials, & Safety
- Building Environment
- Technical Evaluation & Application

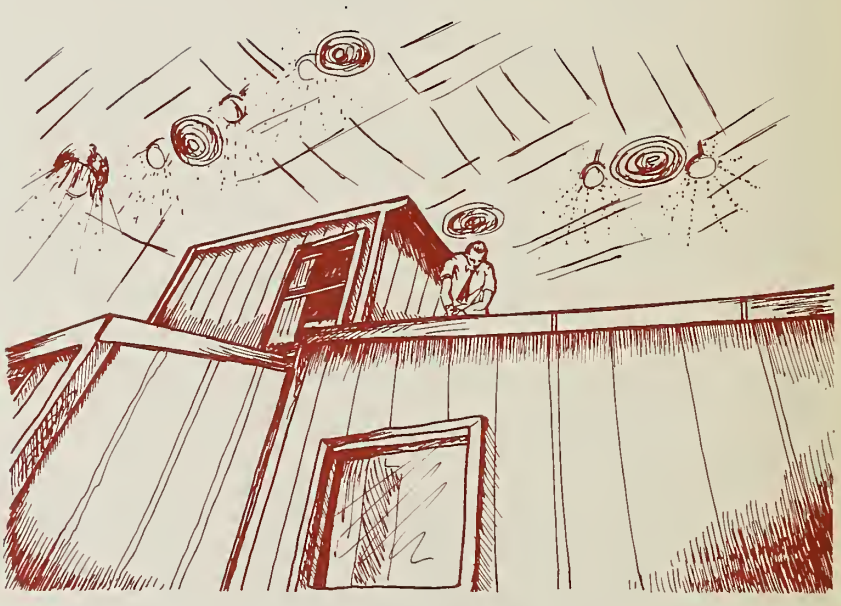
In addition, three offices manage interdisciplinary teams tackling complex problems, provide technical inputs to the States and local government, and provide client liaison:

- Building Codes & Standards
- Housing & Building Technology
- Energy Conservation

As part of NBS, the Center shares the Bureau's modern laboratory complex in Gaithersburg, Maryland, a short distance from the nation's capital.



The Center has seven environmental chambers, the largest of which is 9 x 12 x 18 m (30 x 40 x 60 ft), in which whole buildings have at times been tested for their thermal characteristics. Here, a modular house is readied for a test in a chamber that can control temperatures from -45 to 65°C (-50 to 150°F) with controlled humidity. Other than houses, the chambers have been used to evaluate refrigerator trailers, concrete block structures, a Coast Guard inflatable raft (whose CO_2 charge was found to lose pressure at very low temperatures), and a fleet of postal service trucks, which were tested for their pollution emissions for different speeds and fuel types.



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CENTER FOR BUILDING TECHNOLOGY
Institute for Applied Technology

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