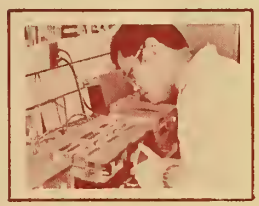
building technology project summaries 1976

CENTER for BUILDING TECHNOLOGY
Institute for Applied Technology
National Bureau of Standards
Department of Commerce



FOREWORD

The Center for Building Technology (CBT) provides the technical and scientific bases for criteria and standards that improve the usefulness, safety, and economy of buildings. CBT research also aims at conserving building materials and energy. CBT's activities support the building technology programs of Federal, State and local government; assist design professions, building officials, and the research community by developing improved design criteria; and assist manufacturers of building products by developing methods for evaluating innovative building materials.

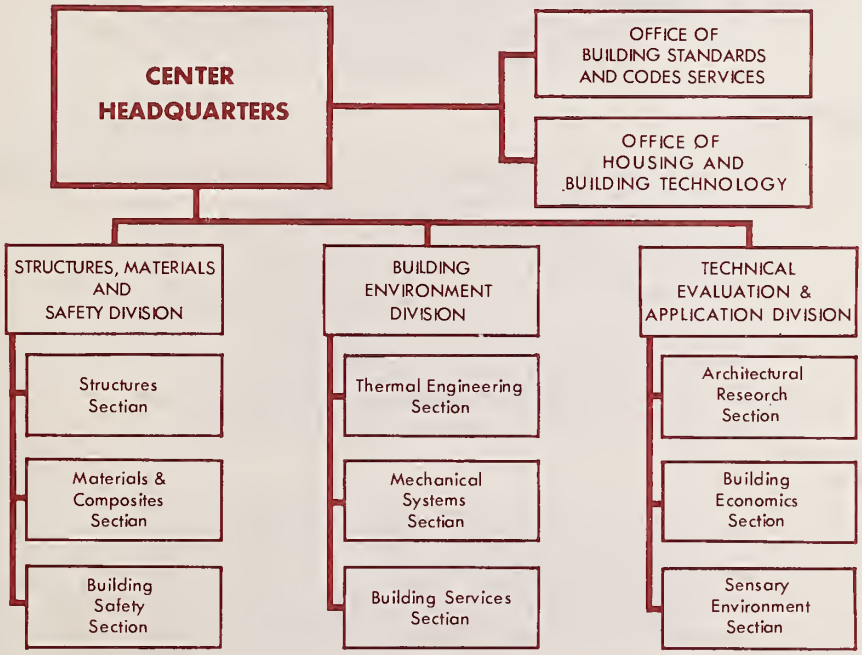
Individual projects may emphasize one or more of the Center's typical activities in providing improved knowledge, in usable form, to the building community. Typical activities include: problem analysis to define and characterize needs for improved building practices; research to obtain vital new knowledge; technical problem solving to develop improved practices from the best available knowledge; dissemination of results to users in the building community; and impact analysis to show how well the Center's work has met the building community's needs and whether elements of the original problem remain unresolved or new problems exist. In all these activities the Center works closely with other organizations in the building community which aid in the Center work or use its results.

This report summarizes CBT's research for calendar year 1976. Each summary lists the project title, its progress, point of contact within CBT, and sponsor. This report supersedes the 1976 edition of SP446, which covered the 1975 CBT projects.

The reader is encouraged to review two other companion documents. NBS Special Publication 439, *The Center For Building Technology: A Perspective,* presents the facilities and approaches to building research at the Center. Special Publication 457-1, *Building Technology Publications 1976,* lists and indexes all recent reports published by CBT.

The summaries presented in this report are arranged by subject-matter categories, such as Structural Studies, Economics, and so on. These categories, however, were selected merely to group like projects—not to reflect the structure of the Center. CBT's organization is shown below.

CENTER FOR BUILDING TECHNOLOGY



MOBILE HOMES

CODES AND STANDARDS

HOUSING AND BUILDING TECHNOLOGY

Energy Conservation

ENERGY CONSERVATION PLANNING

Robert R. Jones -301-921-3892
Office of Housing and Building Technology

Sponsor: National Bureau of Standards

Under this project, energy conservation programs are planned and energy conservation technology is promoted. Plans are developed to coincide with programs at other Federal agencies, such as the Federal Energy Administration, the Energy Research and Development Administration, and the Department of Housing and Urban Development. Center staff members prepare background studies and analyses for interagency multidisciplinary projects. Energy program planning efforts are presented to interested groups. In this context, the Center's energy conservation research, consultation, and technical advice reaches all segments of the building community. Also, responses are made to requests for new research findings and reference data, and for technical information.

PARTICIPATION IN THE AMERICAN SOCIETY OF HEATING, REFRIGERATING, AND AIR-CONDITIONING ENGINEERS STANDARD 90-75, "ENERGY CONSERVATION IN NEW BUILDINGS"

Frank J. Powell -301-921-3637
Building Environment Division

Sponsor: National Bureau of Standards

The Center will participate on the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 90-75, "Energy Conservation in New Buildings" Project Committee and its Sub-Panels, to provide interpretations on the current 90-75 Standard and to revise and update this standard. The use of the standard throughout the building regulatory community is a major goal.

Previously, CBT developed the energy design criteria that were published as *Design and Evaluation Criteria for Energy Conservation in New Buildings*, which present requirements for thermal resistance and air leakage in building envelopes and energy-saving practices in mechanical and electrical design. These criteria were used by ASHRAE and the Illuminating Engineering Society, to develop Standard 90-75 of ASHRAE. In its *Standard 90-75 Workbook*, ASHRAE cited the standard, promulgated in August of 1975, as its "most significant contribution to our society." Arthur D. Little Associates in a study under contract to the Federal Energy Administration (FEA) estimated the use of Standard 90-75 will save 60 percent of the energy used in office buildings. Further, construction cost savings would be 63 cents per square foot. Additional costs of insulation and glazing are more than counter-balanced by the savings in mechanical systems.

The State of Wisconsin adopted a portion of the standard and the State of Virginia adopted the entire standard. Michigan and New Jersey are considering the standard. An adaptation of 90-75 was developed by the Building Officials Conference of America, and a draft version was prepared for other model code groups by the Board of Coordination of Model Codes. Proposed regulations of the FEA cite the standard as a path to eligibility for Federal assistance to States in energy conservation planning.

DEVELOPMENT OF ENERGY CONSERVATION STANDARDS FOR EXISTING BUILDINGS, THE AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS STANDARD 100

Frank J. Powell -301-921-3637
Building Environment Division

Sponsor: National Bureau of Standards

Because of the large number of existing buildings, the American Society of Heating, Refrigerating and Air-Conditioning Engineers Standard 100 may have a much greater impact on the Nation's energy consumption than standards for new buildings. Under this project, the Center will play a leading role in generating technical data for this standard. The results of other CBT research will be especially helpful, in developing the technical data by relying on such research activities as roofing, thermal insulation, and energy efficient building services. This activity will also serve as a valuable link with CBT activities on performance-based standards for building energy conservation in new buildings.

PROGRAM MANAGEMENT FOR STANDARDS DEVELOPMENT

Jim L. Heldenbrand -301-921-3892
Office of Housing and Building Technology

Sponsors: Department of Housing and Urban Development, Energy Research and Development Administration

Conceptual models, economics and technical data, and performance criteria do not come easily from the mass of data that is being developed on the way buildings use energy. This project is the management framework under which these data will be developed for building energy performance standards and for manuals of accepted practice for energy conservation in new building design. The project provides for monitoring and coordinating the research efforts to develop performance standards, appraising the sponsors of progress, and liaison with the building community and public officials. Last year, the output of this project was a white paper on "Energy Conservation Standards" and a draft of the split residential/commercial program. Project management also chaired a task force working group on national energy conservation standards and made a presentation to the Energy Research Council Task Force on Thermal Standards.

ENERGY BUDGET APPROACH TO BUILDING STANDARDS

William L. Carroll -301-921-3503
Building Environment Division

Sponsors: Department of Housing and Urban Development, Energy Research and Development Administration

This project is an integral part of the development of building energy performance standards. It approaches energy budgets by way of classification schemes for buildings, their service systems, their use and their environments, and the development of a calculation methodology. Likewise, significant climatic parameters will be identified and coordinated with the building classification parameters into an overall set of building energy performance measures. Correlations between climate parameters and energy consumption will be developed. A methodology will be developed to determine the climate classification for actual typical weather data for any particular location.

Finally, all these will be combined into an overall energy budget methodology, which will be described in several National Bureau of Standards reports: one for residential buildings, one for commercial buildings, and one covering the development of the methodology itself.

ENERGY USE IN BUILDING OPERATIONS

S. Robert Hastings -301-921-3595
Technical Evaluation and Application Division

Sponsors: Energy Research and Development Administration, Department of Housing and Urban Development

To develop realistic energy budgets, the effects of user behavior on energy consumption must be considered. This project will provide those data. It will collect and organize data on energy consumption in single-family residences and office buildings. Where existing data are inadequate, methods will be designed for collecting and evaluating new data. The results of this project will be incorporated in the energy analyses used in developing building energy performance standards and in predicting their energy impacts. In addition, this project will assist in describing the architectural (non-mechanical) characteristics of typical single-family and attached residences, and typical office buildings. Where it is difficult to describe the architectural characteristics of a typical building, or to select prototypes for a particular building type, a special methodology will be provided.

PILOT TEST OF THE CONCEPTUAL BUILDING ENERGY PERFORMANCE STANDARDS DOCUMENT

Jim L. Heldenbrand -301-921-3892
Office of Housing and Building Technology

Sponsors: Department of Housing and Urban Development, Energy Research and Development Administration

This project will provide an early test of the effects of new building energy performance standards. Its purpose will be to validate the final approaches selected by means of a pilot test by representative users: architects, engineers, builders, designers, financial institutions, and building regulatory officials. An important facet of the research will be user acceptance, which is just as necessary to BEPS success as is its technical reliability.

ILLUMINATION CRITERIA FOR BUILDINGS

Gary T. Yonemura -301-921-2177
Technical Evaluation and Application Division

Sponsor: Energy Research and Development Administration

The goal is to develop, test, and quantify the illumination required for visual performance in support of building energy performance standards. Energy consumed for artificial illumination also has a secondary heat liberating effect on building heating and cooling loads; this in turn can be a large factor in energy conservation for certain building types or climates.

WINDOW RESEARCH FOR ENERGY CONSERVATION

Belinda Lowenhaupt Collins -301-921-2177
Technical Evaluation and Application Division

Sponsors: Energy Research and Development Administration, Department of Housing and Urban Development

The goal of this project is to develop a comprehensive method for evaluating window performance in support of building energy performance standards. Key objectives include quantification of the heat transfer properties of windows, identification of user requirements, development of a cost-benefit analysis, and assessment of window design strategies to optimize natural light and ventilation. Results from these analyses will provide criteria and data for assessing the costs and benefits of windows in the development of energy budgets for new buildings.

COMPUTER PROGRAMS FOR ENERGY ANALYSES

William L. Carroll -301 -921 -3503
Building Environment Division

Sponsors: *Energy Research and Development Administration, Department of Housing and Urban Development*

This project will develop a set of computer routines and programs that will allow energy budgets to be predicted for selected classes of commercial buildings. In effect, this project provides the overall computational support to building energy performance standards development. Although this project is just beginning, today's understanding of building energy performance through computerized simulation will have to be advanced significantly before it is completed.

NATURAL VENTILATION FOR ENERGY CONSERVATION

Charles M. Hunt -301 -921 -3512
Building Environment Division

Sponsor: *National Bureau of Standards*

This project will assess the energy savings and comfort provided by controlled natural or forced ventilation. The project also will develop guidelines for designing and retrofitting buildings with a view toward the optimal use of the natural cooling effect of outdoor air. Researchers will select a house and instrument it for measuring temperature distribution and relative humidity throughout. Inside-outside changes in pressure also will be measured.

Tests are planned both in the Center's environmental chamber and in the natural environment. In the chamber, fans capable of producing air movement between selected cross-ventilation sites equivalent to 0.1 to 5 air changes per hour will be used. Natural ventilation between selected windows will be observed. A ventilation model will be developed and tested against experimental data. The results of this study will be made available to the public through the National Bureau of Standards and outside publications such as the American Society of Heating, Refrigerating and Air-Conditioning Engineers Journal. The technical data developed under this program will be used in future energy conservation standards.

SUPPORT FOR THE COMMUNITY SERVICES ADMINISTRATION'S WEATHERIZATION ASSISTANCE PROGRAM

Richard W. Crenshaw -301 -921 -3595
Technical Evaluation and Application Division

Sponsor: *Community Services Administration*

The poor are often exposed to extreme temperatures or are forced to spend large amounts of their income for energy. Since the cost of energy is significantly increasing, the Federal government has begun a program to help these people retrofit their homes to reduce energy consumption.

The project is reviewing and evaluating the performance of the Community Services Administration's program, providing technical assistance where possible, and evaluating the effectiveness of various weatherization techniques. Evaluation will consider durability, cost, safety, user acceptance, energy savings, and the best combinations of weatherization techniques.

EFFECTS OF RESOURCE IMPACT FACTORS

Stephen F. Weber -301-921-3701
Technical Evaluation and Application Division

Sponsor: Energy Research and Development Administration

Public Law 94-385, "The Energy Conservation and Production Act," calls for the development and implementation of performance standards for new buildings to achieve the maximum practicable improvements in energy efficiency. The performance standards being developed at the Center are expected to take energy prices into account. Resource Impact Factors (RIF's) are being suggested as a means of accounting for environmental, social, institutional, and national-interest issues related to energy resources. This project addresses the question of whether the energy prices used in determining the standards should be the actual market prices or prices adjusted by RIF's. It is conceivable that the use of RIF's could lower the energy consumption allowed by the standard by as much as 40 percent.

The Center has completed a report sponsored by the Federal Energy Administration entitled, *The Effect of "Resource Impact Factors" on Energy Conservation Standards for Buildings*. Under the current project sponsored by the Energy Research and Development Administration, this report is being sent to a group of over 80 readers selected from industry, building standards committees, and government. These readers will be asked for comments and suggestions to be incorporated into a revised, more definitive version of the report. To disseminate the research results, an article summarizing and extending this work is to be published in *Energy and Building*, a new international journal expected to have wide readership among architects, builders, standards and code officials, and all segments of the building community.

ENERGY CONSERVATION IN BLENDED CEMENT

James R. Clifton -301-921-3407
Structures, Materials and Safety Division

Sponsor: Energy Research and Development Administration

At present, portland cement manufacturers use almost 1 percent of the energy consumed in the United States. The replacement of a portion of portland cement by a suitable waste product such as fly ash will result in a substantial energy savings and also will alleviate waste disposal problems. Electric utilities now produce about 30 million tons of fly ash annually. While blended cements have seen only limited use in the United States, their value has been demonstrated by extensive use in other industrialized countries.

In this project, the behavior of blended cements containing fly ash and blast furnace slags will be compared with those of portland cements to develop relationships between composition, microstructure, and performance. The effect of the replacement materials on the alkali-aggregate reaction and the sulfate resistance of cements will be evaluated to provide a basis for the development of needed durability performance tests and criteria. This work will be brought to the attention of the cement industry and cement users

through symposia and workshops on blended cements. The Center is also participating on the American Society for Testing and Materials committees concerned with Cements (C1) and Waste Materials (E38). Through this participation, CBT is playing an active role in the establishment of performance tests and criteria for blended cements and for broadened use of waste materials in construction.

Energy Conservation in Communities

ENERGY CONSERVATION IN COMMUNITIES

John D. Ryan -301-921-3741
Office of Housing and Building Technology

Sponsor: National Bureau of Standards

Communities offer unique opportunities for energy conservation. Interaction between buildings, joint exchanges of energy and services, areawide management, and economies of scale all hold out the hope of future savings. Unfortunately, such symbiotic aspects have not been explored thoroughly. This project exists to fill that research void. Its general plan is first to outline the community's unique energy conservation potential -- as distinct from that of individual buildings or industrial processes. The product will be a complete program plan, with options, for the Center for Building Technology and outside organizations concerned with improved community services. During the planning period, technical information exchange will include workshops and seminars as well as publications.

MODULAR INTEGRATED UTILITY SYSTEMS: SYSTEMS ANALYSIS

John D. Ryan -301-921-3741
Office of Housing and Building Technology

Sponsor: Department of Housing and Urban Development

From the Center's standpoint, Modular Integrated Utility Systems (MIUS) is an experiment in total energy management and conservation. As an experiment then its operation needs to be continuously evaluated on a number of fronts: energy performance, economic performance, plant reliability, and environmental impact. Only a good score in all these areas will promote the MIUS concept. In its support role, the Center will be preparing a number of analytical reports.

The data collected will be used as the basis for a comprehensive comparative evaluation of residential total energy. This will include analysis of energy performance, environmental economic performance and plant reliability. The evaluation will be based on impact analysis of several alternative energy systems.

The comparative systems analysis will produce monthly evaluations based on site loads and also aggregated evaluations, both actual and referenced to "standard" operations (i.e., typical weather, ideal component performance, etc.) The economic analysis will produce monthly cost data and also aggregated life-cycle cost and profitability analyses. The environmental analysis will include combustion and cooling towers, emissions and noise impacts in a comparative framework.

MODULAR INTEGRATED UTILITY SYSTEMS: DEMONSTRATION

John R. Schaefgen -301-921-3741
Office of Housing and Building Technology

Sponsor: Department of Housing and Urban Development

This demonstration is intended to actualize the Modular Integrated Utility Systems (MIUS) concept and to obtain sufficient data to permit investors to appraise its cost-effectiveness and risks. Its key objectives are: the collection and analysis of data on the financial performance of MIUS; a chronicle and evaluation of the institutional impediments to the implementation of MIUS; collection and analysis of data on the technical performance of MIUS compared with available alterna-

tives; analysis of site utility demand characteristics; and an analysis of the environmental effects of MIUS discharges.

The approach is to construct a MIUS demonstration facility in the new community at St. Charles, Maryland starting in 1977. It will provide electric power, heating and cooling, domestic hot water, wastewater processing, and solid waste management with energy recovery to approximately 700 dwelling units and 18,580 square meters of commercial shopping center and other space, as well as a 8,360 square meter school. CBT will evaluate the institutional impediments to MIUS and design the measurement system, collect and analyze the data, and evaluate MIUS.

MODULAR INTEGRATED UTILITY SYSTEMS: TOTAL ENERGY SYSTEM

C. Warren Hurley -301 -921 -3521
Office of Housing and Building Technology

Sponsor: Department of Housing and Urban Development

The objective of this project is to measure the performance of the Jersey City Summit Plaza, Total Energy System. The work involves the operation, and maintenance of a data-aquisition system. During the project, some 300 system parameters will be monitored at 5-minute intervals by a data acquisition system. The monitoring will provide information about on-site electrical and thermal loads (heating, cooling, and hot water), service reliability, component efficiency, and fuel consumption. The information is collected on computer tape at the test facility and analyzed at the National Bureau of Standards.

STANDARDS FOR SOLID WASTE SAMPLING

David J. Mitchell -301 -921 -3293
Building Environment Division

Sponsor: National Bureau of Standards

Energy recovery from solid waste is a promising alternative and partial solution to the solid waste problem. Before it can be counted on, however, much research is needed. This project is part of that research. It will develop accurate laboratory test procedures, methods of measurement and sampling techniques for solid wastes (refuse), and determine the resource recovery and calorific heating values for refuse derived fuels (RDF). The project's first activities will be the preparation of samples for tests by bomb calorimetry specialists. Since the Department of Housing and Urban Development intends to make the Modular Integrated Utility Systems approach commercially viable, these laboratory efforts must provide the foundation for measurements of integrated (as well as free standing) incineration systems. This work will focus on guideline criteria for sampling, which will be required if RDF is ever to be a commercial success.

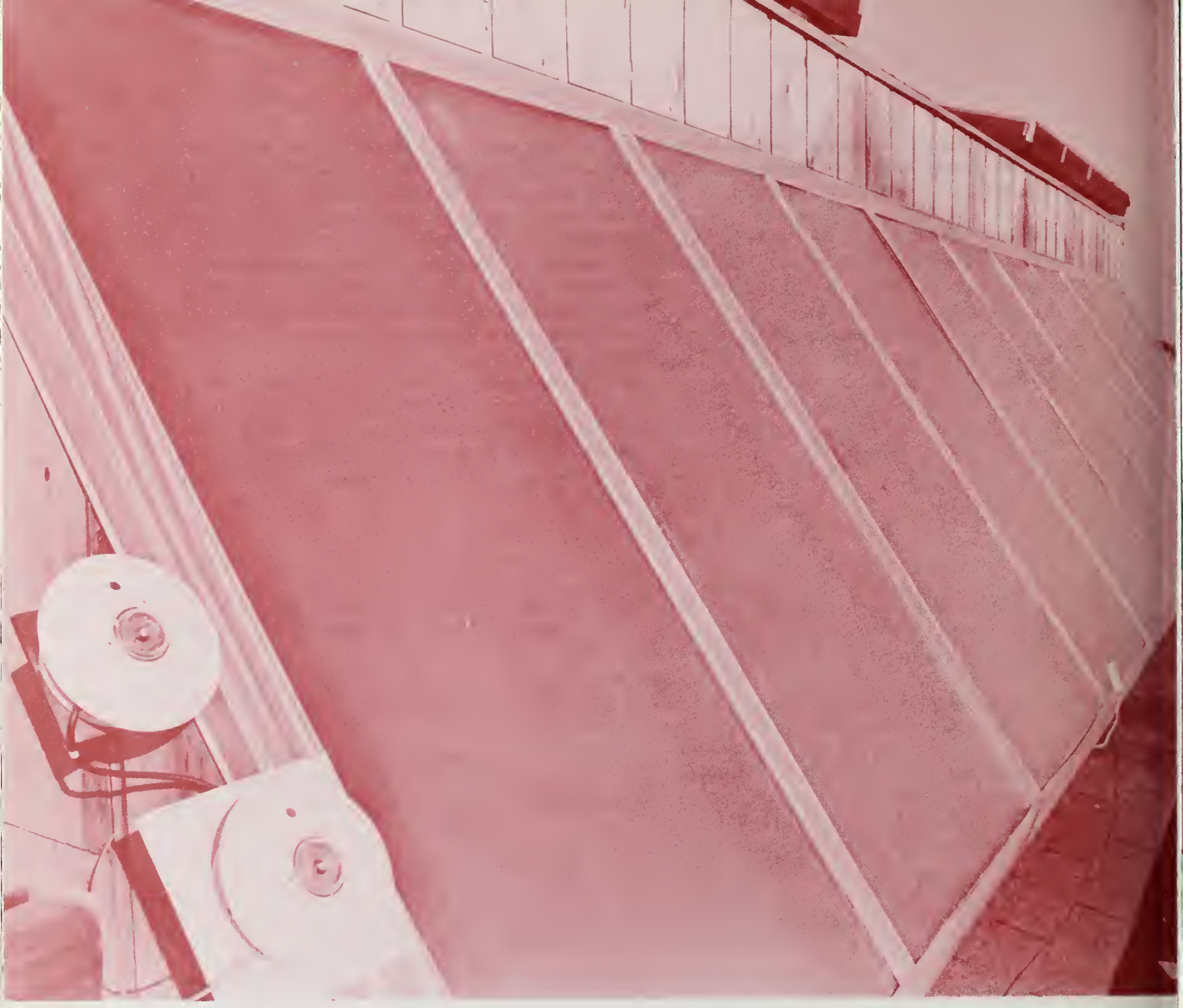
ADVANCED TECHNOLOGY MIX-ENERGY SYSTEMS PROGRAM TECHNICAL ADVISORY SUPPORT

Clinton W. Phillips -301-921-3741
Office of Housing and Building Technology

Sponsor: Energy Research and Development Administration

The Center is providing technical assistance to the Argonne National Laboratory's Program Planning Committee and its technical sub-committees on the Advanced Technology Mix-Energy Systems (ATMES) Program. This program examines the present need, the available technology and recommends the needed research to the Energy Research and Development Administration (ERDA). Emphasis is on optimizing the community characterization and community integrated utility system.

NBS participation in this project will help produce technical results that will be incorporated into ATMES/ERDA published reports. For example, the Center's work on the integrated utility system simulation program will be made available to the design profession.



Solar Energy

SOLAR ENERGY RESEARCH FOR THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

Robert D. Dikkers -301-921-3285
Office of Housing and Building Technology

Sponsor: Department of Housing and Urban Development

The Solar Heating and Cooling Demonstration Act of 1974 (Public Law 93-409), and related Federal legislation provides for the Department of Housing and Urban Development (HUD), the Energy Research and Development Administration (ERDA), and other Federal agencies to design, develop, and demonstrate solar heating and cooling applications in buildings. To aid participating agencies and other interested groups in the conduct of the Federal solar energy program, a National Plan for the Solar Heating and Cooling of Buildings Program, ERDA 76-6, has been prepared and published by ERDA.

In brief, Public Law 93-409 and ERDA 76-6 specify that HUD will use the research and technical support of the National Bureau of Standards in its solar programs. For example, last year the Center developed an interim document, *Intermediate Minimum Property Standards for Solar Heating and Domestic Hot Water Systems*, which when finalized in 1977 will serve as a companion to the Federal Housing Administration Minimum Property Standards, the basis for mortgage insurance under a number of HUD housing programs.

Other activities under this project include: (1) developing plans to define technical data needed to evaluate system performance; (2) establishing a data center for the storage, processing and dissemination of technical and non-technical non-instrumentation data; (3) monitoring and evaluating data obtained from solar residential demonstration projects; and (4) preparing improved performance criteria for solar equipment and dwellings.

SOLAR ENERGY STANDARDS

James E. Hill -301-921-3512
Building Environment Division

Sponsor: Energy Research and Development Administration

The goal of this project is to participate in the development of new standards associated with solar heating and cooling systems and components and to apply the results of the Center's solar energy research in an effective way. During the past fiscal year, a Center for Building Technology staff member participated on two separate committees of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, which drafted standards for testing and rating solar collectors and thermal storage devices, respectively. Two draft standards were completed in June 1976 and were submitted to the Society membership for vote. A second member served as Chairman of the American Society for Testing and Materials Subcommittee E21.10, "Solar Energy Utilization," which was organized to identify and draft standards. A list of high-priority standards was completed and work began on the drafting of several of them in the areas of durability and reliability.

TEST METHODS FOR SOLAR COMPONENTS

James E. Hill -301 -921 -3512
Building Environment Division

Sponsor: Energy Research and Development Administration

Under this project, the Center is designing, developing, and publishing the test methods that will be used on solar collectors and thermal storage devices. The test methods specify the apparatus, instrumentation, and detailed procedures for each device. For each type of product, the Center constructed the test equipment and is continuing to determine how it might be improved. Such test procedures are needed to compare the performance of solar components on a common and equitable basis, as is done with fuel-burning equipment, air conditioners, and heat pumps. Standard test procedures will not only make possible a basis for selecting products, but will provide a basis for the next generation of design.

Based on Center test methods, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) versions of the tests were approved by the 30,000 members of the Society as ASHRAE Standards 93-77 and 94-77.

TESTING OF RETROFITTED SOLAR HEATING, VENTILATING, AND AIR-CONDITIONING SYSTEM

James E. Hill -301 -921 -3512
Building Environment Division

Sponsor: Energy Research and Development Administration

A solar heating and cooling system has been designed and installed in a four-bedroom house on the National Bureau of Standards grounds. This project involves the operation, data acquisition, and evaluation of the solar energy system. Measured data will be compared with predicted data for several operation modes to determine the adequacy of the analytical models to predict fossil fuel savings. The solar system consists of flat-plate collectors with water/ethylene glycol as the transfer fluid, water storage, and an absorption air conditioner within the existing forced-air system of the house. The approach is to evaluate the system during typical summer and winter operation and compare it with predicted performance.

During this year, the first year's test data and operating experience are being published. The publication will include comparison of measured and predicted results as well as a comparison with test data taken previously when the house was equipped with conventional equipment. Further experimentation will be done with a modified system (new solar collector panels added) to examine alternate operating and control strategies that minimize the use of auxiliary energy.

GSA/MANCHESTER SOLAR EVALUATION

James E. Hill -301 -921 -3512
Building Environment Division

Sponsor: Energy Research and Development Administration

A federal office building was designed and constructed in Manchester, New Hampshire to provide a laboratory for the installation of both recognized and innovative energy conservation technologies.

The construction of the building was completed in September 1976. It is seven floors tall, with a two-level basement parking garage, located on a site of about 3,600 m^2 (40,000 ft^2) in downtown Manchester.

Four separate arrays of solar collectors are mounted on the roof of the building. They will be used to heat water or a water-ethylene glycol solution; the energy will be used to supplement the conventional energy sources in the building for heating, cooling, and hot water.

The plan for this project is to initially test at least one individual panel in each of the four arrays to determine to what extent the collector performance meets or exceeds the requirements in the original purchase specification. Following this, performance data will be gathered on the entire collector array over at least two heating and two cooling seasons to determine the contribution made by the solar subsystem in reducing requirements for fossil fuels.

COMMERCIAL SOLAR ENERGY DEMONSTRATION

Robert D. Dikkers -301-921-3285
Office of Housing and Building Technology

Sponsor: Energy Research and Development Administration

Under this project, an interdisciplinary team of Center personnel is participating in the preparation of draft standards and performance criteria and in the evaluation of commercial applications of solar heating and cooling. As an overall approach to the use of solar heating and cooling, it covers many areas: comparisons of actual with predicted solar system and component thermal performance; the evaluation of operational problems (accidents, equipment failures, substandard performance); the examination of institutional constraints (code problems); development of improved performance criteria for solar systems and commercial buildings, preparation of plans to develop and implement standards; and the review and monitoring of tests and evaluations of solar equipment.

INTERNATIONAL COOPERATION ON SOLAR ENERGY

Elmer R. Streed -301-921-3503
Building Environment Division

Sponsor: Energy Research and Development Administration

Most countries of the world are investigating the promise of solar energy. But all this activity, in a relatively new field, could lead to confusion and duplication unless international standards are developed for terminology, testing, materials, and performance. This project deals with the exchange of technical information and the joint conduct of the following three subprojects: (1) investigation of solar heating and cooling systems; (2) coordination of research and development on solar heating and cooling components; and (3) performance testing of solar collectors.

Economics

TECHNIQUES FOR ECONOMIC EVALUATION

Harold E. Marshall -301-921-3701
Technical Evaluation and Application Division

Sponsor: National Bureau of Standards

The goal of this project is to develop, refine, and apply some of the theories and methods of benefit-cost analysis, risk-benefit analysis, and life-cycle costing to building evaluations, and to make this information available to the building community. To reach the goal, improved analysis techniques will be applied in the areas of energy conservation in buildings, evaluations of building codes, and in other high-interest areas. Results will be published in media that will have impact on the building community. Last year, the project published eight articles in economics and building journals; completed three major reports and lectures; published seven papers in the Proceedings of the Purdue University Conference on Heating, Ventilating, and Air-Conditioning Equipment and Components for Buildings; and conducted a Federal Workshop on Building Economics. Similar work will result from this year's work on the economics of solar heating and cooling, building codes, reducedsized venting, and energy conservation.

UNIFORM LIFE-CYCLE COSTS

Rosalie T. Ruegg -301-921-3701
Technical Evaluation and Application Division

Sponsor: National Bureau of Standards

A recent Government Accounting Office report to Congress virtually demanded the use of Life-Cycle Costing (LCC) in the evaluation of all Federal projects. The Center for Building Technology is taking the lead in the development of LCC methods and their application to buildings. The LCC concept is the only thorough and reliable way to make rational decisions about acquiring new space: Is leasing, construction, or renovation the best method? Further, as a result of the energy crisis, the need to take a life-cycle approach that takes into account energy use as well as first costs is particularly urgent. Project results will be made available to Federal agencies, building researchers, and other interested parties. The researchers will also participate in workshops, briefings, seminars, and professional meetings.

ECONOMICS IN ENERGY STANDARDS

Stephen R. Petersen -301-921-3701
Technical Evaluation and Application Division

Sponsor: Energy Research and Development Administration

This project will provide analytical support to the building energy performance standards program (see Energy Conservation Section), including overall framework development, building construction cost data, and life-cycle cost analysis of energy-related building operations. The technical challenge is to provide a straightforward methodology for use in optimizing new building designs for energy conservation as a function of climate, fuel costs, and other variables that can influence building energy use. Together with the cost data and energy savings data, a great deal of design information is being made available to help minimize potential life-cycle building costs at the design stage.

THE ECONOMICS OF WINDOW DESIGN

Rosalie T. Ruegg -301 -921 -3701
Technical Evaluation and Application Division

Sponsor: National Bureau of Standards

The capital and maintenance costs of windows, as well as their psychological benefits and costs, are important to the overall efficiency of window selection. This economic analysis of windows will provide a more complete approach to the optimal selection of windows. Economists from the Center will develop a life-cycle cost model for analyzing alternative window characteristics, in a given application, in terms of the combined net effect of thermal, construction, and maintenance costs. Using thermal data developed by the Center's Thermal Engineering Systems Section, and costs of alternative window characteristics described by the Center's Architectural Research Section, the life-cycle cost model will be exercised for selected window applications. Measures of psychological benefits and costs identified by the Center's Sensory Environment Section will also be related to the life-cycle costs.

THE COSTS OF RECYCLING BUILDINGS

Stephen F. Weber -301 -921 -3701
Technical Evaluation and Application Division

Sponsor: National Bureau of Standards

Millions of dollars are spent by builders each year to demolish existing buildings and to replace them with new buildings. Millions of dollars also are spent by municipal governments to upgrade public utilities and services to meet the changed demands brought about by new construction. Large costs in terms of traffic delays, congestion, and disruption of commerce result from new construction in areas of high land use.

The question is: Is all this necessary? To answer that, the Center will identify and suggest ways of measuring the life-cycle cost impacts of recycling and new construction on communities, and prepare a report for use by others facing such a decision. Further, the impacts will be developed for three levels of recycling -- making additions, interior gutting, and component replacements with cosmetic improvements -- for estimating the dollar costs of resource expenditure. In a recent National Symposium for the Building Community, recycling was termed "the wave of the future," and the need for life-cycle information to guide members of the building community was deemed critical.

It is urgent that the question be addressed now because the scarcity of capital funds, fuel, and building materials is causing communities increasingly to seek means of economizing in the provision of public services.

ECONOMIC ANALYSIS OF LEAD-PAINT ABATEMENT TECHNIQUES

Robert E. Chapman -301 -921 -3701
Technical Evaluation and Application Division

Sponsor: Department of Housing and Urban Development

Lead paint abatement techniques differ not only in their efficiency at removing the hazard from the environment, but also in their installation and maintenance costs. Thus, the choice of abatement technique is neither readily apparent nor easily determined. This study will help the urban planner make the choice among abatement techniques for a given set of constraints (e.g., surface type, substrate condition, or occupancy status) by providing an analysis of costs and

by relating those costs to the performance levels of alternative techniques. The project results so far were published as "Economic Analysis of Experimental Lead Paint Abatement Methods: Phase I," which analyzes the key factors in the determination of cost based on empirical cost data and a method for identifying and measuring variations in a abatement method cost. An article, "Lead Paint Poisoning: A Closer Look at the Costs," which describes the cost procedure, recently appeared in the *Journal of Housing*.

ECONOMIC BENEFITS OF LEAD PAINT ABATEMENT

Joseph G. Kowalski -301-921-3701
Technical Evaluation and Application Division

Sponsor: Department of Housing and Urban Development

Mandatory abatement of the lead paint hazard would conceivably cost over $20 billion. But the repair and remodeling industry's gross output in 1975 was only $25 billion. Thus lead paint abatement could have an enormous impact on this important sector of the housing industry. However, lead paint abatement investments could be associated with benefits well in excess of their costs, or benefit levels could be so low as to justify no investments. Until procedures are developed that can be used for measuring benefits, the optimal level of abatement remains unknown. This project will gather data on the causes and consequences of elevated lead levels in the blood. Second, a model relating the benefits and costs of lead paint abatement will be developed. Third, estimates of the benefits and costs of lead paint abatement will be made for a representative local housing submarket in order to test the model and to determine the range of confidence that can be placed around benefit estimates. Finally, economists will identify additional research required to narrow the range of the benefit estimates.

Thermal Studies

THERMAL MEASUREMENT TECHNOLOGY

Chock I. Siu -301 -921 -3503
Building Environment Division

Sponsors: National Bureau of Standards, Department of Housing and Urban Development

Three areas of thermal engineering measurement are being pursued in this project. The first is a new and improved guarded-hot-plate apparatus for use as an absolute method of measuring the thermal conductivity of insulation and building materials. This apparatus is to replace the present apparatus (circa 1937) now approved by the American Society for Testing and Materials Standard. The second area of research is that of thermal comfort measurement. Here the emphasis has been on the scanning radiometer as a measuring device. The third area is air infiltration measurements, an area where the center is contributing to the developing and testing of both the infiltrometer (sulfur hexafluoride as a tracer) and the permeameter. The technical data developed under this project will be incorporated into standards for thermal conductivity measurements and for air infiltration measurements. Results are made available through the Center's publications and those of the American Society of Heating, Refrigerating and Air-Conditioning Engineers. A symposium on the development of thermal comfort data will present the project's outcome to the public.

ATTIC VENTILATION STUDIES

Chock I. Siu -301 -921 -3503
Building Environment Division

Sponsor: National Bureau of Standards

Although it has been commonly accepted that attic temperature during hot summer days can be significantly reduced by attic fans, their effectiveness as an energy conservation measure has been questioned. This project exists to answer that question. Its test bed will be an instrumented house at Twin Rivers, New Jersey. To be measured during the tests are the energy consumption for cooling, airflow through the attic, air leakage in the room below (with and without fan), outdoor temperature, humidity, solar radiation, and wind speed and direction. Temperatures at four or more different locations will be measured at several levels. Heat flux meters will be used to measure the ceiling heat flow under fan-off and fan-on conditions. Separately, in the case of air-conditioning ducts in the attic space, duct airflow and the temperature rise in the duct will be measured to assess the heat gain into the supply and return air streams. The output of this study will be published by the National Bureau of Standards, an excerpt of which also will be published in the American Society of Heating, Refrigerating, and Air-Conditioning Engineers Transactions. The data developed will impact building energy performance standards.

THE LATENT COOLING PERFORMANCE OF A FAN-COIL UNIT

James Kao -301 -921 -3521
Building Environment Division

Sponsor: Tri-Services Committee of the Department of Defense

In many military dormitories and family housing units, space cooling is provided by fan-coil units having low latent load capacity. When these units are used in Gulf Coast regions having high outdoor dew point temperatures [averaging 21 to 24° C (70 to 75° F)], insufficient moisture is removed from the indoor air. Air infiltration processes continually introduce moisture-laden outdoor air into the building. The result is that condensation forms on cold indoor surfaces whenever the fan-coil unit operates. The moisture then leads to mildew, fungus growth, and moisture damage.

Indoor summer condensation problems can be remedied by modifying certain operating parameters of the fan-coil units to increase their latent load capacities. However, information provided by fan-coil unit manufacturers is not sufficient to perform these modifications.

The experimental plan is to instrument a fan-coil unit in a room-sized environmental chamber. The environmental chamber would simulate various indoor conditions when the fan-coil unit was operated under steady-state conditions. Certain operating parameters of the fan-coil unit such as chilled water temperature, chilled water flow rate, and airflow rate across the coil would be varied, and the effect of these operating parameters on the latent load capacity of the fan-coil unit would be investigated.

AIR FORCE ENERGY CONSERVATION HANDBOOK

Douglas M. Burch -301 -921 -3512
Building Environment Division

Sponsor: United States Air Force

To reduce spiraling energy costs, the Air Force needs an energy conservation program that can be easily applied to utility systems and buildings on its many bases. To help them with such a program, the Center is developing a 2-volume handbook specifically for Air Force needs and energy problems. It will cover adjustments to central heating plants, distribution systems, and building equipment. Other areas include power factors, waste heat recovery, lighting, hot water heating and cooling. Volume I will be targeted for base-level managers and will contain management guidelines on energy conservation. Volume II will be targeted for base-level engineers and technical personnel and will contain detailed technical material and advice on energy conservation.

GROUND FLOOR HEAT LOSS

Douglas M. Burch -301 -921 -3512
Building Environment Division

Sponsor: National Bureau of Standards

Ground floor heat loss is thought to represent a small fraction of the total heat loss of a home. And yet what we now know about this phenomenon is based on a very small amount of research. To reduce our uncertainty about this heat loss -- in an age that has become suddenly energy conscious -- this project will be an analytical investigation of heat loss characteristics

from below-grade basements and slabs-on-grade using a mathematical simulation and a finite-difference-solution technique. Design heat-loss factors will be determined for a range of earth conductivities, different amounts and positions of edge insulation, and floor dimensions.

THERMAL ASPECTS OF WINDOWS

Tamami Kusuda -301 -921 -3501
Building Environment Division

Sponsor: National Bureau of Standards

The approach to thermal-related aspects of windows is to relate artificial lighting and energy requirements to the solar thermal and daylight characteristics of selected window types. Data compatible with the Bureau's Load Determination Program will be gathered. These will permit researchers to determine the effect of any window type on the total energy consumption of any building. Last year, extensive calculations were made to analyze net energy transfer through windows of different sizes and designs. The calculations included the daylight trade-off, fenestration management (control of shading and insulation), and nighttime thermostat setback. This year, the project will prepare thermal guidelines for architects and will participate in a Federal workshop on window research.

HEAT TRANSFER IN THERMAL ENERGY STORAGE

Bradley A. Peavy -301 -921 -3503
Building Environment Division

Sponsor: National Bureau of Standards

The storage of heat for later use is an important factor in lowering the Nation's energy dependence. To this end, analytical models will be needed to study the thermal performance of such thermal storage devices as air-rock and water-sand. In addition, studies need to be undertaken to understand the potential for using these devices underground in large earth masses. To date, a scale model of a wet-sand system has been built; its actual thermal storage capacity is being used to fine-tune the theoretical model. Similar work is underway with an air-rock system. Preliminary results of the work are being published in *Solar Energy, 1976* and the research results will be used in the updating of American Society for Heating, Refrigerating and Air-Conditioning Engineers Standard 94-77, "Methods of Testing Thermal Storage Devices Based Thermal Performance."

PERFORMANCE OF INSULATED BUILDING ELEMENTS

Chock I. Siu -301 -921 -3503
Building Environment Division

Sponsor: National Bureau of Standards

Under this project, CBT will develop and construct a laboratory apparatus for studying the heat-transfer properties of large parts of buildings (wall, roof, ceiling, floor, and combinations) under static or dynamic environmental conditions. The project is being undertaken for two reasons: to provide bases for nationally accepted standard test methods and to provide reliable data on this particular area of heat transfer.

AIR INFILTRATION IN REACTOR CONTROL ROOMS

Charles M. Hunt -301-921-3512
Building Environment Division

Sponsor: Nuclear Regulatory Commission

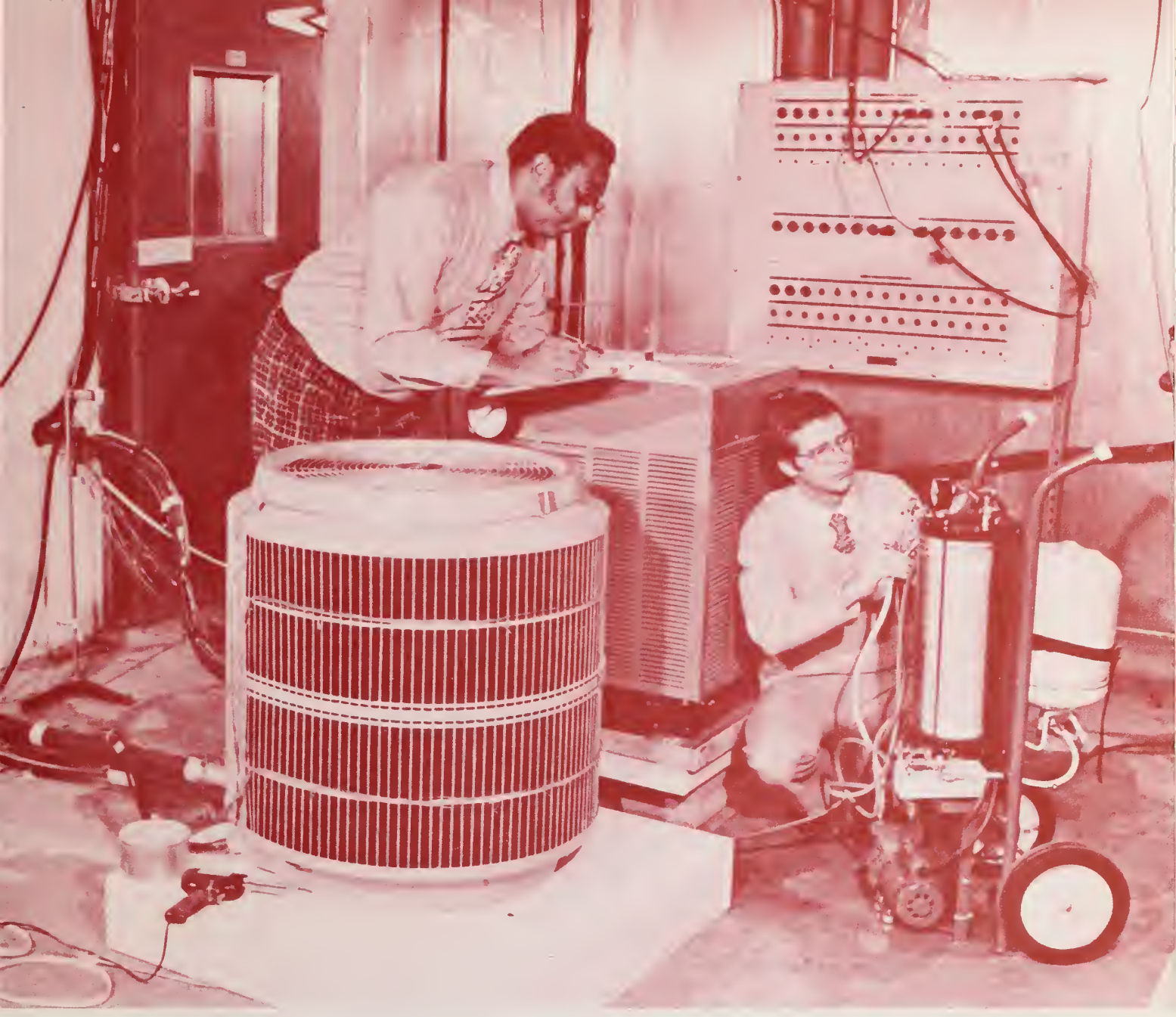
This project will measure the air leakage of atomic power plant control rooms by the use of sulfur hexafluoride (SF_6) tracer gas. At present, there is no established procedure for measuring the air leakage into a control room operating in the emergency mode -- shut off from its surroundings. However, CBT has developed a SF_6 tracer gas technique, which is well suited to this task. The rate of dilution of SF_6 (in parts-per-billion) is used to estimate the air infiltration rate. Control rooms at Beaver Valley, Pennsylvania, and Brown's Ferry, Alabama, have been visited and specific measurements and sampling problems identified. Leakage rate measurements were made at Beaver Valley and a letter report was sent to the Nuclear Regulatory Commission. Small-scale tests of possible loss of tracer by absorption on concrete or plaster also were made prior to full-scale tests in a control room. The full scale study of Brown's Ferry will begin this year.

PARTICIPATION IN THE AMERICAN SOCIETY FOR TESTING AND MATERIALS COMMITTEE C16, "THERMAL INSULATION"

Frank J. Powell -301-921-3637
Building Environment Division

Sponsor: National Bureau of Standards

Under the project, CBT participates in the work of the American Society for Testing and Materials (ASTM) Committee C16, "Thermal Insulation," to assist them in the development of consensus standards on the characteristics and performance of thermal insulation. Also, there is some controversy concerning ASTM methods for testing thermal performance of insulation. It is the responsibility of CBT to assist in the resolution of these measurement discrepancies and to take the initiative in developing new test methods that determine thermal performance more accurately. Special emphasis is given to broadcasting the results of CBT research through their incorporation in standards.



Mechanical Systems

OIL BURNER ENERGY CONSERVATION

George E. Kelly -301-921-3521
Building Environment Division

Sponsor: Federal Energy Administration

CBT research has found that significant energy and dollar savings are possible through oil burner modifications. In field work involving 429 oil burners, it was determined that tuneups improved average steady-state efficiency from 74.2 to 76.1 percent. This translates to a seasonal fuel savings of about 3 percent. Moreover, virtually all the units were found to be oversized in relation to design heating requirements. Other simple retrofitting changes have been found to have fuel savings ranging from 8 to 21 percent. A homeowner's brochure and a serviceman's guide to reducing the nozzle size on oversized units have been written and are now being published. The Center will soon continue this work with evaluations of the installation of sealed combustion systems, stack dampers, flue restrictors, heat reclaimers, and blue-flame burners. This will involve a field study to evaluate the pre-retrofit performance of a number of heating systems, the installation of one or more retrofit options, and a reevaluation of the oil burner's performance.

ENERGY USAGE IN HOUSEHOLD APPLIANCES

Richard A. Grot -301-921-3293
Building Environment Division

Sponsor: Federal Energy Administration

This project will gather actual performance data on the energy usage of major household appliances in a series of six townhouses at Twin Rivers, New Jersey. The data-logging and computer equipment is now installed and its output will be compiled into a report on winter seasonal performance and summer seasonal performance. Overall, the output of the project will be a reliable data base to be used in standardized appliance testing to support the energy labeling program.

APPLIANCE ENERGY LABELING

George E. Kelly -301-921-3521
Building Environment Division

Sponsor: Federal Energy Administration

Over the years, certain consumer products have become known as "energy hogs." Moreover, critical information on energy consumption has been denied to buyers because there was no way of evaluating the operational and energy costs of such appliances. Today, however, the Center is developing laboratory tests, computer models, and calculation procedures to predict the dynamic and seasonal performance of furnaces, hot water boilers, central air-conditioners, and heat pumps. Close contact is being maintained with various manufacturers and standards writing organizations to ensure the accuracy, fairness, and acceptability of these standards. By such interaction, it is hoped that the recommended procedures will be readily adopted as consensus standards by such organizations as the American National Standards Institute, Air-Condition and Refrigeration Institute, American Society of Heating, Refrigerating and Air-Conditioning Engineers, and American Gas Association. The draft test and calculation procedures will be given to the Federal

Energy Administration, which is required by law to publish test procedures for manufacturers to use in labeling their products. Then, the Federal Trade Commission will decide upon the type of label to be placed on each product.

PART-LOAD HEATING, VENTILATING, AND AIR-CONDITIONING EQUIPMENT (LARGE BOILERS)

Joseph Chi -301-921-3521
Building Environment Division

Sponsor: National Bureau of Standards

This project is developing test methods in support of consensus standards for part-load performance and rating of building heating and cooling equipment, particularly for industrial boilers. At present, equipment performance ratings are based on steady-state test methods. This has led to a continuing dispute on their actual field performance. Ultimately, laboratory methods that more closely simulate field performance will be necessary if manufacturers are to accurately rate their equipment under part-load operation. Part-load ratings will in turn allow designers to use the most energy effective equipment and to design more efficient systems.

Last year, laboratory studies were performed on the dynamic performance of a nonmodulating gas-fired boiler. A test rig was constructed for furnaces and part-load performance testing of a gas-fired furnace and an oil-fired furnace began in the laboratory. A mathematical model was developed to predict the part load and seasonal performance of nonmodulating boilers. During this year, the Center will complete the process of generalizing its boiler model to large commercial and industrial boilers and compare predicted performance with experimental results available on total energy boilers. The results of this work will be published and presented to the American Boiler Manufacturers Association for their use.

EVALUATION OF THE STIRLING ENGINE

David A. Didion -301-921-2994
Building Environment Division

Sponsor: National Bureau of Standards

The performance of the Stirling engine to date has been solely measured by its manufacturer and was generally oriented toward transportation applications. Therefore, a laboratory evaluation of a prototype engine (10 horsepower) is underway in this project to verify claims under total energy application conditions. Conclusions from this laboratory evaluation will be used to verify or modify manufacturer's performance claims for the larger total energy engines.

The 10-horsepower Stirling engine has already been set up in the laboratory and most of the data collected. In addition, a first cut at mathematically modelling the Jersey City Total Energy site (with its diesel generator sets) has been completed. The analysis of both these efforts and the report writing remains. The report and conclusions will be forwarded to those industry and Government groups with an interest in

Total Energy and Stirling engine systems: the Department of Housing and Urban Development, the Energy Research and Development Administration, the Department of Defense, Philips Corporation, General Electric, the American Gas Association, and selected design firms.

COMPUTER CONTROL OF HEATING, VENTILATING, AND AIR-

David A. Didion -301 -921 -2994
Building Environment Division

Sponsor: National Bureau of Standards

Early on, the National Bureau of Standards (NBS) realized that its own campus -- including numerous buildings and laboratories of various sizes -- was a national laboratory for developing energy conservation techniques -- especially those that promise savings to large government and industrial consumers. Earlier Center programs have already accounted for a nearly 20 percent savings in fuel consumption. Under this project, a central computer control facility is being installed to save a further 20 percent in one test building. The computer will allow a closely time-phrased control and shutdown of all external air during hours when the building is not occupied (for a savings of 28 percent); will give enthalpy control of all external air (for a 12 percent savings); and off-coil temperature re-set (15 percent). Eventually, these techniques will be applied to all the NBS buildings in Gaithersburg as well as other Federal buildings nationwide.

Plumbing

TECHNOLOGY OF WATER CONSERVATION

Mary Jane Orloski -301 -921 -3293
Building Environment Division

Sponsor: National Bureau of Standards

Many answers have been suggested for the problem of water shortages. Two frequently mentioned are (1) matching the supply water quality to the usage with a dual-pipe supply system, and (2) technological innovation such as reduced-flow systems and fixtures. However, before such techniques can be depended upon, a rigorous testing program must be undertaken to evaluate the claims of the new systems and their impact on the users. For example, a recently marketed reduced-flow toilet had to be flushed twice for hygenic reasons, thereby doubling its water consumption. This project, then, will undertake a number of tasks: establish an evaluation matrix for immediate application to the wide variety of water and energy conserving systems and fixtures; prepare performance evaluation testing procedures for classes of devices; conduct selected testing of water economy measures; determine base-line demand from field studies in instrumented dwellings; and prepare laboratory simulations of usage patterns. The results of the work will be made available to manufacturers and code groups alike, as well as to conservation organizations and the utilities.

PLUMBING SYSTEMS DESIGN CRITERIA

Paul A .Kopetka -301 -921 -3293
Building Environment Division

Sponsor: National Bureau of Standards

This project is the core activity studying the total water supply distribution and wastewater drainage for buildings. It aims at providing the technical basis for the American National Standards Institute A40 Performance-Based "National Plumbing Code." The economic cost benefits derived from laboratory reduced-size vent findings are being accepted in the building community; model code amendments have been drafted based upon CBT recommendations. The validity of a new plumbing vent performance standard that protects the public is now being demonstrated in the field. The 40-year-old Hunter Water-Demand Design Curves are also being updated. These and other activities are continuing, with special emphasis this year on storm drainage criteria. The outcome of this research are reports that constitute a major source of plumbing data for national and international groups. Presentations of technical findings are made at wide variety of meetings, and to the American Society of Plumbing Engineers, American Society of Sanitary Engineering, the National Conference of States on Building Codes and Standards, Federal Workshops, and Federal Agency planning groups.

PARTICIPATION ON THE AMERICAN NATIONAL STANDARDS INSTITUTE STANDARD A40, " THE NATIONAL PLUMBING CODE"

Lawrence S. Galowin -301 -921 -3293
Building Environment Division

Sponsor: National Bureau of Standards

The American National Standards Institute (ANSI) Standard A40, "National Plumbing Code," was last revised in 1955 and is in serious need of upgrading. The Center for Building Technology (CBT) participation on this standards committee is an opportunity for CBT to be influential in the language adopted in the code, particularly as related to the performance approach. The impact of the new code will fall directly upon the financial interests for developers, builders, and users of residential, commercial, and industrial buildings. The interactions with other water supply and drainage engineers, inspectors, designers, and contractors provide special situations for direct exchange of needs and for problems to be investigated in laboratory projects.

LIQUID WASTE MANAGEMENT RESEARCH

Richard A. Symuleski -301 -921 -3293
Building Environment Division

Sponsor: National Bureau of Standards

Water quality problems have in some areas brought a complete halt to building. At present, the building industry has a need for a longer look at the problems and solutions of wastewater treatment. The project will survey all liquid-waste disposal methods and will develop a series of manuals and guidelines. Together, these sources will constitute an information base that the developer, municipal official, planner, and general public alike can use in determining the alternatives available in providing new housing with environmentally sound wastewater management plans.

CRITERIA FOR WATER SERVICES

Richard A. Symuleski -301 -921 -3293
Building Environment Division

Sponsor: National Bureau of Standards

The National Sanitation Foundation has recently formed a committee to develop information about suspected contamination of water from polyvinyl chloride piping materials. Current CBT activity in the Modular Integrated Utility Systems demonstration has identified the need to determine the measurement technology and quality criteria necessary for nonpotable water reuse. The problems of known contaminants of organic, inorganic, and biological content entering water supplies from fixtures and piping materials (e.g., heavy metals, leachates from plastics, lead from joints and packing) require precise measurement. This project is a first attempt to evaluate the quality of such water at the tap. It will determine required levels of precision and statistical validity of measurements to satisfy prescribed water quality criteria, evaluate gas chromatography as a measurement technology, and recommend possible strategies for automation of evaluated test methods for laboratory and field applications. This project produced the paper "An Evaluation of the Applicability of Pyrolysis-Gas-Liquid Chromatography for the Identification of Microorganisms in Water and Sewage Treatment Plant Effluents," which was presented at the Third National Conference on Complete Water Reuse.

Sensory Environment

WINDOW RESEARCH: DESIGN

Belinda Lowenhaupt Collins -301 -921 -2177
Technical Evaluation and Application Division

Sponsor: National Bureau of Standards

This project covers the behavioral aspects of CBT's multidisciplinary study of windows. Although the simplest solution for reducing energy consumption might be the total elimination of the window, this may not always be desirable from the standpoint of the user, the designer, or the engineer. As a result, the benefits and drawbacks of windows must be specified in many terms before design criteria can be developed.

A CBT survey of the importance people hold for windows has brought together for the first time a wide variety of information on the subject. This information was published as Building Science Series 70, *Windows and People: A Literature Survey*. The study found that one function performed by a window is the addition of a dynamic, active quality to an interior environment. Other functions are to give a view to the outside world and contribute to room spaciousness. The broad appeal of this review is suggested by the fact that it has been republished in the United Kingdom, Italy, and France (as *Les fenetres et les gens*).

ENVIRONMENTAL SIMULATOR

Robert A. Glass -301 -921 -2177
Technical Evaluation and Application Division

Sponsor: Energy Research and Development Administration

Under this project, a mobile energy conservation laboratory will be built. The laboratory will enable studies of the thermal and visual characteristics of spaces -- with and without windows, and with windows of different types and sizes. The flexibility of the laboratory will enable us to study the effect of various orientations of a window on daylight and heat-transfer. The advantage of the proposed simulator over existing laboratory apparatus is the ability to investigate the combined effects of solar radiation, wind pressures, temperature, and rainfall of actual outdoor conditions on the indoor environment and on exterior wall elements, and, more important, on windows. This facility will also permit behavioral studies to be performed in areas such as human reactions to window configurations.

NOISE IN AND AROUND BUILDINGS

Simone L. Yaniv -301 -921 -2177
Technical Evaluation and Application Division

Sponsor: National Bureau of Standards

This project is designed to uncover the human response to noise in buildings. It is generally agreed that human response to noise depends upon three parameters: its amplitude, its frequency spectrum, and the variations of both of these quantities with time. To describe the noise environment, these three parameters must be combined. The result is a psychophysical scale and algorithm that relates the noise parameters to a subjective response. The function actually used in developing the psychophysical scale and algorithm depends upon which aspects of the response and the noise are considered to be most important. Since this selection is made on the basis of a human judgment, it is not surprising that there are numerous such scales (at

least 35), each reflecting the particular idiosyncracies of the researcher and his subjects.

This project is designed to evaluate existing scales to determine their relative importance and effectiveness in developing appropriate acoustical ratings for building environments -- ones which will satisfy the needs for quiet. The work will impact new building construction of all types since it will contribute to the development of codes, standards, and regulations for acoustical properties of both rooms and buildings.

COLOR APPEARANCE

Gerald L. Howett -301 -921 -2177
Technical Evaluation and Application Division

Sponsor: National Bureau of Standards

The first part of this research deals with surface color. Color coding is a common method for rapidly communicating safety information. Many Government agencies and trade associations have developed over the years their own sets of colors for use in identifying different categories of traffic signs or warning labels. Most of these color codes contain, for example, a red, but the exact shade of red prescribed is not the same in all the codes. This project aims at encouraging all these groups to choose their colors from a single, limited set of precisely defined colors with explicit meanings.

The colors of the standard code have already been selected and proposed to the American National Standards Institute (ANSI) Committee Z53, "Safety Color Code for Marking Physical Hazards." The remaining effort will involve consultation on the detailed wording of the Z53.1 standard, and of other standards that will reference the same colors.

The second part of the research is on illumination color. The intensity of flashing lights strongly affects visibility, but not in proportion to the intensity. Thus a light of twice the intensity is not twice as conspicuous. The project will concentrate on developing a conspicuity scale that numerically measures subjective impressions. Lights differing not only in intensity, but in color, flash rate, or other physical parameters, under different viewing conditions, can then all be comparatively rated on this common scale.

VISUAL ENVIRONMENT

Gary T. Yonemura -301 -921 -2177
Technical Evaluation and Application Division

Sponsors: National Bureau of Standards, Energy Research and Development Administration

Preliminary studies conducted at the Center indicate that the current experimental basis for reccommending levels of illumination may be in error for many common tasks. Experiments will be conducted to quantify the amount of light really needed by describing the performance of the eye under real-world conditions.

A second part of this research is related to veiling reflectance. One of the most important determinants of lighting quality is the geometrical distribution of light flux and the resulting veiling reflectance (reflectance that partially obscures the details seen because it

reduces the contrast). A good lighting system even with a lower illumination level can be more effective visually than a system with a higher illuminance but with poor geometric light distribution. Five different types of luminaires are being installed in the Manchester Energy Conservation Demonstration Building. They all use the same power, but may differ significantly in their effectiveness for visual performance.

The results of the study will go to the Illuminating Engineering Society (IES), the principal source for lighting standards. They are the sponsors of the American National Standards Institute standards on lighting. The research results will be presented to the Illuminating Engineering Research Institute, the research arm of IES. Data also will be presented to the American Institute of Architects.

VISUAL ALERTING SYSTEMS: AMERICAN NATIONAL STANDARDS INSTITUTE SECRETARIAT

Kenneth L. Kelly -301-921-2177
Technical Evaluation and Application Division

Sponsor: National Bureau of Standards

The visual-alerting-systems secretariat was established at the Center for Building Technology. A prime function of this project will be to maintain liaison with all committees of the American National Standards Institute (ANSI) that are developing or applying visual alerting systems, as well as with similar committees in government, industry, and other standards organizations. Also, it is anticipated that ANSI Committees Z53, "Safety Color Code for Marking Physical Hazards," and Z35 on "Accident Prevention Signs and Tags," will transfer their secretariats from the National Safety Council to the CBT facility. A combination of these committees, either through formal fusion by ANSI or at least by maintenance of a coordinating joint secretariat, will create an entity corresponding in function to the International Standards Organization Committee TC80 on "Safety Colours and Safety Signs." All major research work on visual alerting, both here and abroad, thus will be coordinated through CBT.

BUILDING ILLUMINATION STANDARDS

A. Theodore Hattenburg -301-921-3293
Building Environment Division

Sponsors: Energy Research and Development Administration, General Services Administration, National Bureau of Standards

This project will develop, under combined General Services Administration, Energy Research and Development Administration and the National Bureau of Standards sponsorship, new technical data and test requirements for standards related to energy-conserving lighting requirements in all buildings. The results will have impact upon the Building Energy Performance Standard. Initially the project will provide a framework for the major steps toward development of performance standards for illumination. The project also will study the energy use, efficiency, and interactions of the lighting system with other elements in buildings, such as the heating, ventilating and air-conditioning systems, water systems, windows, furnishings, architectural

design. Overall energy impacts of dissipated heat gains will require a great deal of evaluation. The final outcome of the study will be new standards; to that end, the Center is expanding its contribution to committees of the Illuminating Engineering Society, the National Electric Code, and the American National Standards Institute.

Materials

DURABILITY PREDICTION METHODOLOGY

Larry W. Masters -301-921-3371
Structures, Materials and Safety Division

Sponsor: National Bureau of Standards

Durability is often the most important attribute required of a building component or material, but it is the most difficult attribute to measure and predict on the basis of short-term tests. At present, short-term tests are seldom satisfactory for predicting long-term performance. Thus, there is an urgent need to improve durability prediction techniques. This research is aimed at developing durability standards. It involves developing and applying a general method for durability prediction, maintaining seven natural exposure stations, studying the effects of natural weathering and accelerated laboratory weathering, and undertaking a complementary program with the Canadian National Research Council to develop international standards for natural weathering of building materials. To date, a recommended practice for durability prediction has been prepared and balloted in the American Society for Testing and Materials (ASTM) Committee E6.22, "Durability Performance of Building Construction," and the important phase of durability prediction, identification of failure mechanisms, has been studied using metal-to-metal electrical contacts. The methodology is now being applied to organic coatings. Eventually, the recommended practice for durability prediction will be processed as a consensus standard by ASTM. ASTM and other standards-setting groups will use the standard to improve durability tests. It also is planned to present the philosophy of the standard and the results of the Canadian program to international standards groups.

SOLAR MATERIALS: PROBLEMS DEFINITION

Leopold F. Skoda -301-921-3371
Structures, Materials and Safety Division

Sponsor: Energy Research and Development Administration

This project will study the currently available operating solar systems, with an eye to the problems now being experienced. This survey will then form the basis for identifying needed standards particulary atuned to the demands and environment of solar components. The outcome of the study will be guidelines for the use of solar materials, and a list of areas where materials standards are most urgently needed. The final report will be a publication distributed to the Energy Research and Development Administration, other Federal agencies, and to standards setting groups such as the American Society for Testing and Materials, for use in the development of materials standards.

MATERIALS STANDARDS: ABSORPTIVE COATINGS

Larry W. Masters -301-921-3371
Structures, Materials and Safety Division

Sponsor: Energy Research and Development Administration

While numerous standard test methods have been developed for coatings in building construction, the performance requirements involved in solar systems are quite different. For example, temperatures on the absorptive surface may reach 250 °C or greater, but standard test methods for coatings seldom involve temperatures as high as 100 °C. Thus standard test methods to evaluate absorptive coatings are urgently needed.

The purpose of this project is to prepare draft standards. These standards will be based upon results of laboratory studies and will be submitted to the American Society for Testing and Materials for consideration as consensus standards.

MATERIALS STANDARDS: COLLECTOR INSULATION

McClure Godette -301 -921 -3441
Structures, Materials and Safety Division

Sponsor: Energy Research and Development Administration

Any loss of heat, other than through the transfer fluid, reduces the efficiency of a solar collector. For this reason, evaluation and identification of thermal insulation as a material to provide resistance to the flow of heat from the back of the absorber plate or side of the collector is of primary importance. For the user, proper insulation results in an increase in the heating or cooling efficiency; for the Nation, it promotes our energy independence.

The project will involve a detailed study of solar insulation materials. Environmental conditions within the solar collector, and properties of the insulation material that contribute to the performance and durability of insulation will be identified and evaluated. Assessment of this work will lead to the development of draft performance standards to be submitted to the American Society for Testing and Materials.

MATERIALS STANDARDS: SEALANTS AND GASKETS

Larry W. Masters -301 -921 -3371
Structures, Materials and Safety Division

Sponsor: Energy Research and Development Administration

Numerous standard test methods have been developed for sealants and gaskets for use in buildings. However, the performance requirements for sealants and gaskets used in solar energy systems are not entirely covered by the available standards. The purpose of this study is to prepare draft standards for liquid sealants and preformed gaskets. The standards will be based upon the results of laboratory studies to evaluate available materials according to the performance required in service. Among the factors that affect gasket performance are temperature and temperature cycling, moisture, ozone stress, ultraviolet radiation, and contact with transfer fluids. The final standards will be submitted to the American Society for Testing and Materials for consideration as a consensus standards.

MATERIALS STANDARDS: COVER PLATES

Elizabeth J. Clark -301 -921 -3441
Structures, Materials and Safety Division

Sponsor: Energy Research and Development Administration

Many solar collector designs incorporate a cover plate whose purpose is to transmit solar energy while both protecting the inner areas of the collector from damage and reducing the heat losses. Any loss in the transmittance of solar energy through the cover plate results in a decrease in the efficiency of the entire solar heating and cooling system. However, the transmittance and other important properties of cover plate materials are frequently deteriorated by sunlight and the tempera-

tures encountered in solar collectors. Thus, there is an overriding need for standards to be developed for cover plates of solar collectors.

Many standard test methods are available to evaluate materials such as glass and plastic. However, the performance requirements for cover plates of solar collectors are not entirely covered by the existing test methods. The purpose of this project is to prepare a draft performance standard for cover plate materials for flat plate solar collectors. The standard will be based on the results of laboratory studies to evaluate available materials according to performance required in-service. The draft is being developed in cooperation with the American Society for Testing Materials (ASTM) Task Group on Cover Plates E21.10, "Solar Heating and Cooling Application," and will be submitted to ASTM for consideration as a consensus standard.

CORROSION OF METALS

James R. Clifton -301-921-3407
Structures, Materials and Safety Division

Sponsor: National Bureau of Standards

The corrosion of pipes and structural metals can increase the maintenance cost and affect the structural integrity of buildings. In the past, the Center's work on epoxy coatings for reinforcing bars has resulted in the incorporation of epoxy coated bars in a large number of recently constructed concrete bridges. This year, work will concentrate on metallic pipes. Electrochemical techniques and weight change measurements will be used to evaluate the effectiveness of inhibitors in reducing the corrosion of black steel, copper, and galvanized pipes. The effects of pH, water flow rate, soluble salts, and concentration of inhibitors on corrosion rates also will be determined. The results of this project will be published in the open literature and brought to the attention of the American Society for Testing and Materials, the National Association of Corrosion Engineers, corrosion scientists, and government and industrial organizations. A conference on corrosion of metals in buildings will also be held at the Bureau.

PERFORMANCE OF ROOFING

Robert G. Mathey -301-921-3407
Structures, Materials and Safety Division

Sponsor: National Bureau of Standards

A performance approach to the evaluation of bituminous membrane roofing is needed to overcome the traditional roadblocks that prescriptive specifications of roofing materials present. Roofing technology has progressed slowly partly because roofing is a highly fragmented, high-volume, low-profit business. Further, the characteristics of built-up membranes are seldom identified or specified quantitatively. Manufacturers of roofing products need criteria for guidance on the properties of their products. We as a nation need such guidelines from an energy standpoint alone. A conservative estimate suggests that 20 million barrels of

oil per year could be saved by improving roof performance.

The Center has approached this problem by first identifying and studying 20 critical performance characteristics of roofing materials. These include tensile strength, coefficient of thermal expansion, flexural strength, tensile fatigue strength, flexural fatigue strength, moisture expansion, effects of moisture on strength, shear strength (horizontal and vertical), impact resistance, notch tensile strength, creep, wind uplift resistance, weather test, fire resistance, ply adhesion, permeability, abrasion resistance, fungus resistance, tearing, and pliability.

In addition, the project has published a well received study of asphalt viscosities at various application temperatures. Another report showed the effects of insulation on the surface temperature of roof membranes. A proposed standard method of test for the viscosity of asphalt at its service temperature was submitted to the American Society for Testing and Materials and a videotape on roof performance was prepared for the Built-Up Roofing Systems Institute.

PROPERTIES OF RESATURATED ROOF MEMBRANES

Robert S. Mathey -301-921-3407
Structures, Materials and Safety Division

Sponsor: Energy Research and Development Administration

The goal of this project is to develop data on the performance of old bituminous roof membranes that have and have not been subjected to "resaturant" coatings. This information will provide a basis for the selection of materials and procedures for the maintenance of bituminous roofing systems. In addition, it will provide information on the condition of old roof membranes to help with the decision to replace or repair.

Roofing membrane samples for laboratory tests will be selected from buildings that have had part of the roof membrane coated with a resaturant coating. Laboratory samples will include membranes of various ages without coatings and samples with resaturant coatings that were applied 1 to 3 years ago. The laboratory tests will be carried out as described in the National Bureau of Standards report, Building Science Series 55, *Preliminary Performance Criteria for Bituminous Membrane Roofing*.

ROOFING AND COATING RESEARCH FOR THE ARMY

Robert G. Mathey -301-921-3407
Structures, Materials and Safety Division

Sponsor: Department of the Army

This project work will include laboratory tests and evaluations as well as field investigations, directed to the critical roofing, coating, and waterproofing problems of the U.S. Army.

In most cases, CBT staffers are able to visit problem sites and recommend cost-effective fixes based on available technology and experience. Deficiences in current standards and practices are noted as a guide to future research activities.

ORGANIC COATINGS

Paul G. Campbell -301-921-3441
Structures, Materials and Safety Division

Sponsors: Tri-Services Committee of the Department of Defense, National Bureau of Standards

About $3.5 billion is spent annually on paints and allied products, but this represents only 20 percent of the total amount spent each year on painting. The value of the paint is rarely as much as 1 percent of the value of the building or object being painted, yet marketability and subsequent maintenance is dependent on the performance of the coating. Durability and performance studies, test method development, and cooperative efforts with voluntary standards organizations play important roles in improving coating performance and in reducing maintenance costs.

This year, a new field test site will be established for the evaluation of coatings applied to actual buildings. Laboratory tests and outdoor exposures of new coatings will be carried out to evaluate the applicability of existing test methods and, if necessary, develop new ones. The coatings to be studied will include vinyl primers and coatings, water repellent coatings, and latex maintenance coatings. In each case, the results obtained from a range of commercially available materials will be used as the basis for a draft specification for consideration by the military. A series of lectures will be given as part of a new coatings course being developed by the Naval Facilities Engineering Command. The project is of direct benefit to the military by providing them with specifications for the purchase of paints and coatings. However, the Center's draft specifications generally become Federal specifications, in which form they will have a great impact on the industry.

RESTORATION AND PRESERVATION TECHNOLOGY

Geoffrey J.C. Frohnsdorff -301-921-3458
Structures, Materials and Safety Division

Sponsor: National Park Service

The National Park Service maintains many buildings as part of its role in preserving our national heritage. Because of the wide variety of materials and types of construction in historic buildings, the Park Service sometimes requires consultation on paints, mortars, cleaning procedures and preservatives for building materials. The Center's Materials and Composites Section provides consultation and advice when called upon to do so. Examples might be in advising on the selection of paints for the White House, preservatives for an Indian sculpture in the earth, and advising on the possible deleterious effects of cleaning procedures on a stone building. This project makes the services of the Materials and Composites Section available to the National Park Service on a rapid-response basis whenever special knowledge of the durability and preservation of materials in historic buildings arise.

LEAD-PAINT HAZARDS

Harvey W. Berger -301-921-3281
Office of Housing and Building Technology

Sponsor: Department of Housing and Urban Development

Continuing the Center for Building Technology (CBT) research on lead-paint poisoning, this project has examined the cost effectiveness of numerous ways of removing lead paint from the environment and the relationship between lead paint in older houses and body burdens of lead in children. Housing officials, contractors, and homeowners have been provided with a broad spectrum of techniques for either removing or covering up lead paint. CBT also helped local authorities determine the severity of lead poisoning in their communities by producing a manual covering an explicit survey method.

As a result of a CBT-coordinated survey in Pittsburgh, which found low incidences of lead poisoning among children living in lead-paint-contaminated homes, researchers are more seriously considering other environmental factors (lead piping, lead air pollutants) as causes of lead poisoning. The Pittsburgh findings may have avoided large and expensive programs to eliminate lead-paint hazards from housing. This year, work will continue on an evaluation of the accuracy and calibration standards for lead-paint detectors; field testing will continue on paint abatement techniques; and a model will be developed to compare costs, materials, and effectiveness of all abatement techniques.

AVERSIVE COATINGS TO REDUCE LEAD-PAINT POISONING

Paul G. Campbell -301-921-3441
Structures, Materials and Safety Division

Sponsor: Department of Housing and Urban Development

Aversive coatings that will discourage children from eating lead paint flakes have been considered by the Department of Housing and Urban Development. Since little is known about the ability of aversive coatings to retain their deterrent properties over long periods of time, tests for the durability of aversive coatings had to be developed.

For each aversive coating selected for evaluation, three main tasks were carried out: the development of a suitable analytical procedure for determining the quantities of the essential aversive ingredients; a study of extraction procedures; and an evaluation of their ability to be retained on laboratory-prepared painted surfaces after artificial weathering and repeated washing. The outcome of the research was the report, "A Study of the Material Applied to Painted Surfaces."

NONTOXIC YELLOW TRAFFIC STRIPING

Paul G. Campbell -301-921-3441
Structures, Materials and Safety Division

Sponsor: Department of Transportation

The most widely used yellow paint pigment in traffic striping is lead chromate. With the restriction on lead pigments in buildings and the possibility that they will be banned from use in highway markings, there is a need to identify and evaluate the performance of substitute yellow pigments. While this project is specifically concerned with nonlead pigments for

marking paints, the technology gained will provide knowledge about nonlead yellow pigments for use in paints and buildings. In this project, the performance of yellow traffic stripings exposed at the outdoor test sites and by road testing will be evaluated. The results and laboratory tests will be incorporated into a final report on the performance criteria for yellow traffic striping.

EFFECTS OF HERBICIDES ON MASONRY STRUCTURES

James E. Fearn -301-921-3407
Structures, Materials and Safety Division

Sponsor: National Park Service

Vegetation can cause severe damage to masonry structures. This problem is particularly acute for the National Park Service, which is responsible for the preservation of several historic forts along Florida's gulf coast. There the roots of persistent vines and grasses easily penetrate mortar joints and cause them to crumble. To keep the forts free from destructive vegetation requires either a continuing grooming by hand or periodic spraying with herbicides. The use of herbicides is usually less costly and more effective in keeping the vegetation under control. However, there is an important question about the long-term effects of herbicides on the durability and appearance of masonry structures.

The Center for Building Technology is reviewing commercially available herbicides and their use in historic building preservation programs in the United States and other countries. At the same time, the types of masonry units and mortars used in historic buildings that are candidates for herbicide treatment will be noted. Then, the processes by which herbicides might cause deterioration will be identified and a judgment will be made as to whether the types of herbicides commonly used, or considered for use, are likely to cause further damage. Examples of possible effects are dissolution of the materials, swelling of mortar constituents, color changes caused by complexing of heavy metals or nonuniform removal of surface soil, and reducting bond strength between mortar and masonry units.

WOOD FOUNDATIONS AND ARSENIC

Harvey W. Berger -301-921-3281
Office of Housing and Building Technology

Sponsor: Department of Housing and Urban Development

A report submitted to the Department of Housing and Urban Development by the National Concrete Masonry Association indicated that air, dust, and wood samples obtained from houses built with wood foundations contained arsenic. Furthermore, the report stated that the arsenic levels were greatly in excess of toxic limits established by the Occupational Safety and Health Administration for industrial exposures. To investigate this statement, the Center has been called upon to determine the levels of arsenic in dust, soil, wood surfaces, and air, in or near dwellings with wood foundations. The project also will evaluate the way arsenic

leaches from wood and the adequacy of chemical and other tests that show the presence of arsenic.

INORGANIC BUILDING MATERIALS

James R. Clifton -301 -921 -3407
Structures, Materials and Safety Division

Sponsor: National Bureau of Standards

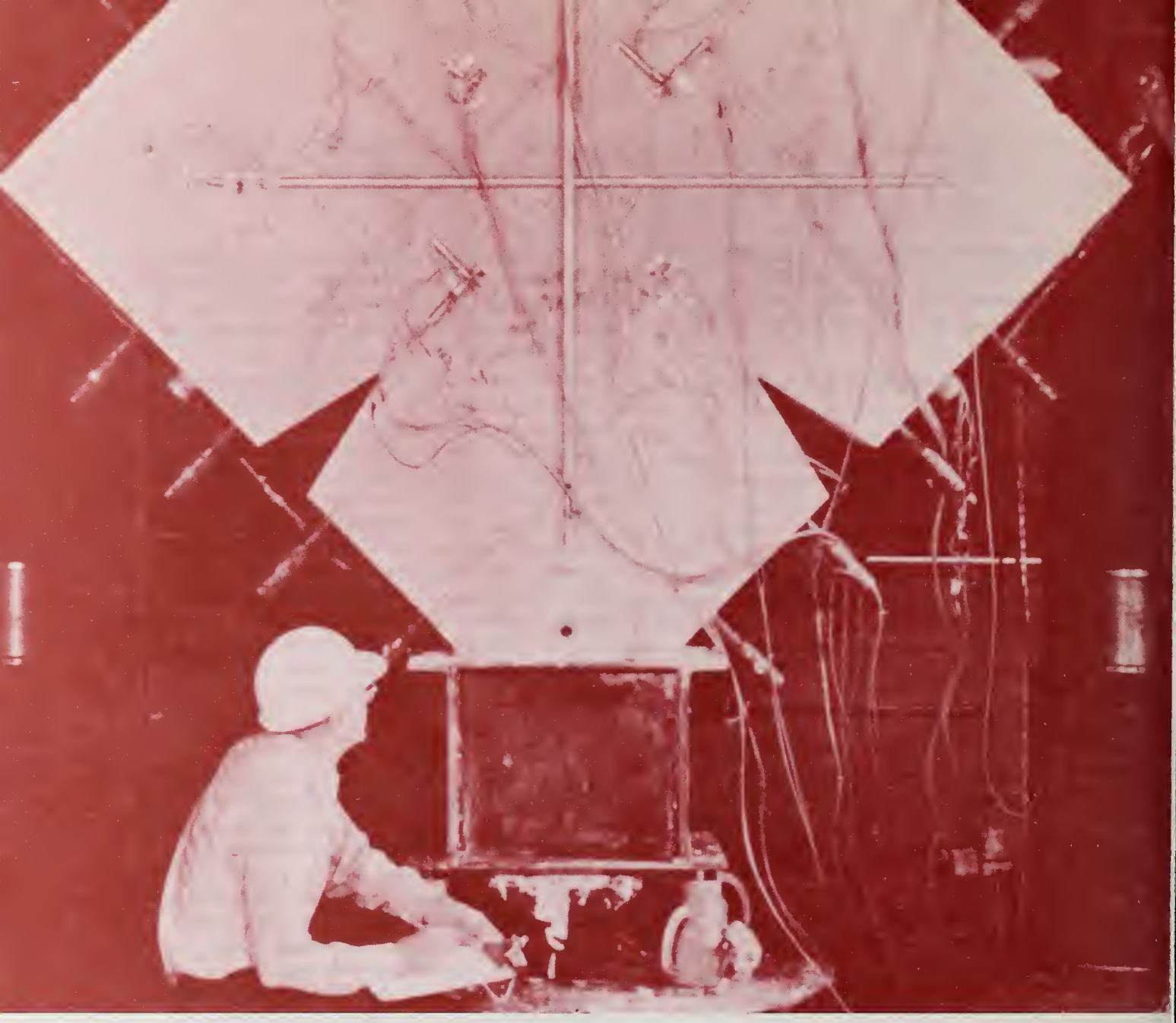
In this project, relationships are sought between in-service performance of inorganic building materials and their composition and structure. Knowledge of these relationships provides a basis for performance tests and criteria. These contribute to improved effectiveness. They also aid in making decisions about the substitution of materials. The porosities, phase compositions, mechanical properties, and durabilities of inorganic materials are determined using techniques that include optical scanning electron microscopy; mercury porosimetry; tensile and compressive strength measurements; fracture mechanics; thermal analysis; and x-ray diffraction. The durabilities of materials to freeze-thaw cycles, to wetting and drying, and to temperature extremes also are being investigated. Nearly completed aspects of the project include a study of the use of waste materials in construction, a report on polymer impregnated fiber-reinforced concrete, and a study of the microstructure of cement paste.

NONDESTRUCTIVE EVALUATION OF BUILDING MATERIALS

James R. Clifton -301 -921 -3407
Structures, Materials and Safety Division

Sponsor: National Bureau of Standards

This project will evaluate nondestructive methods for determining the *in situ* mechanical properties and the physical condition of inorganic building materials. Present studies are concentrating on measuring the properties of concrete and on measuring the moisture content of other inorganic materials. Last year, Center staffers tested concrete using the Windsor Probe, Schmidt Rebound Hammer, Ultrasonic Pulse Velocity measurements, pullout of cast-in-place inserts, and the maturity concept. They also identified the need for development of standard calibration methods and materials for measurements of moisture in building materials. A paper, "Nondestructive Techniques for Evaluating Metallic Artifacts of Historic Interest," also was prepared. In conjunction with other units of the Bureau, staffers are evaluating the feasibility of using neutron diffraction as a method for the analysis of cements, and developing methods for interpretating x-ray diffraction patterns.



Structural

STRUCTURAL RELIABILITY

Bruce R. Ellingwood -301-921-3475
Structures, Materials and Safety Division

Sponsor: National Bureau of Standards

What are the margins of safety and risk in building design? This is an important question -- especially since the costs of excessive safety margins are high, and because there is a critical shortage of certain materials. Moreover, current design criteria do not provide a consistent margin of safety because of failure to explicitly consider uncertainty and risk, and consequently may unduly penalize certain materials and innovative structural designs if extrapolated to apply to them.

Existing realistic data on applied loads and strength of building materials are being compiled and their statistical variability analyzed in an effort to assess reliability as a risk associated with various limit states. The American Concrete Institute standard, which governs concrete design in the United States, has been selected for a case study. Using probabilistic analysis, design criteria consistent with current acceptable risk and uncertainty levels and with the objectives of this standard will be developed. Alternate formats are being studied to see if one material-independent set of load factors can be provided that could then appear in a "loads and general design" type of document.

This research will be of great assistance to national standards organizations in their continuing efforts to set appropriate safety and serviceability criteria to structural design. It also will be helpful to Federal agencies involved in building standards development.

STRUCTURAL MODELING

Edgar V. Leyendecker -301-921-3475
Structures, Materials and Safety Division

Sponsor: National Bureau of Standards

Full-scale testing of structures is seldom practical. As a result, experimental structural research is normally conducted using reduced-scale structural models. However, since the parameters affecting resistance usually cannot all be scaled simultaneously, similitude requirements of the structural model are frequently distorted. The validity of scale model tests is sometimes questioned.

The development of a methodology that would accurately account for the distortions from reduced scale structural models would be a valuable contribution to structural engineering and should lead to cost savings by decreasing the need to test larger models than are necessary. At the Center for Building Technology, preliminary study has resulted in a partial listing of needed research on very large full-scale structures or elements. Examples are composite concrete-steel columns, concrete filled pipe (thin walled) columns, continuous deep beams, and interface shear transfer in reinforced concrete. Current large scale studies in interface shear transfer in nuclear reactor containment vessels will be assisted by these basic studies in structural model distortion.

THE SHEAR TRANSFER PHENOMENON IN REINFORCED CONCRETE

Edgar V. Leyendecker -301 -921 -3475
Structures, Materials and Safety Division

Sponsor: Nuclear Regulatory Commission

The containment building at many nuclear power plants is currently reinforced concrete consisting of a system of orthogonal and diagonal reinforcement in each face of the wall. Large reinforcing bars and high percentages of reinforcing steel are used. Current design assumptions rely heavily upon the resistance of the reinforcing steel and very little on the resistance of the concrete or the resistance contributed by the interaction of the concrete and the reinforcing steel. The mechanism of interface shear transfer may provide a rationale by which these effects can be taken into consideration in the design of the containment building. Improved design criteria could result in substantial savings of reinforcing steel.

Stress or deformation fields and the resulting mechanisms that will be studied in this research occur to some extent on all reinforced concrete building structures, especially when they are subjected to seismic loading. Thus, results from this research will not only be applicable to nuclear power plants but also to the walls, beams, footings, and pile caps in other types of buildings.

This project will begin with laboratory tests on relatively small specimens proportioned from a prototype structure. This approach will allow study of the basic mechanisms before investments are made in large test specimens and test equipment. The initial tests will use quasi-static loading. If found to be appropriate, an experimental program will be continued to further verify the use of the interface shear mechanism using larger test specimens and cyclical loading.

UPDATE EXCAVATION AND FOUNDATION STANDARDS

Felix Y. Yokel -301 -921 -3475
Structures, Materials and Safety Division

Sponsors: Department of Housing and Urban Development, National Bureau of Standards

The National Bureau of Standards (NBS) is cooperating with the American Society of Civil Engineers (ASCE) in the preparation of an updated National Standard for foundations and excavations. The Department of Housing and Urban Development funds are being used to prepare a draft standard. The NBS funds help support the secretariat of the committee, which is a full ASCE committee chaired by the project leader. After reaching committee consensus, this standard will become an official ASCE and American National Standards Institute Standard that can be adopted by reference by the United States building codes. It is hoped that a national standard will help reduce the losses caused by foundation failures which now average 83 billion annually.

IN SITU GEOTECHNICAL MEASUREMENTS

Felix Y. Yokel -301 -921 -3475
Structures, Materials and Safety Division

Sponsor: National Bureau of Standards

The recent emphasis in geotechnical engineering has shifted to *in situ* measurements. This shift has come about from the realization that disturbance and scale factors place unsurmountable limitations on the reliability of laboratory measurements. Likewise, great strides in *in situ* measurement technology have recently been made.

As a first step it is planned to produce calibration techniques for the Standard Penetration Test (SPT), which will in turn lead to an improved SPT standard. Considerable benefits will be derived from an improvement in this test, since it is widely used in soil exploration and foundation design, and more recently in soil liquifaction studies. Calibration will help to clear up the confusion now caused by differences between various test procedures used in the United States and in other countries. In a later stage other *in situ* measurement techniques will be examined, in particular the recently developed pressure meters. Since foundation failures have historically been such an important factor in building loss, the improvements offered by this research will go a long way toward making our buildings safer and longer lasting.

PROVISIONS FOR MINE SUBSIDENCE LOCATIONS

Felix Y. Yokel -301 -921 -3475
Structures, Materials and Safety Division

Sponsor: Department of Housing and Urban Development

This project is preparing a set of guidelines under which the Department of Housing and Urban Development can permit the construction of housing under one of its programs in areas that are already undermined, or areas that are likely to be undermined in the future. These guidelines will cover four areas: Guidelines for Site Evaluation and Acceptance; Guidelines for Site Development and Housing Construction; Supplement to the Minimum Property Standards for Mine Subsidence Areas. Since the mine subsidence problem will become more severe with the increased utilization of our energy resources the guidelines are important and will help reduce losses by recommending appropriate preventive measures.

CAPACITY OF REINFORCED MASONRY SHEAR WALLS

S. George Fattal -301 -921 -3475
Structures, Materials and Safety Division

Sponsor: National Bureau of Standards

Research needs for seismic-resistant masonry construction were identified in a September 1976 National Bureau of Standards/National Science Foundation Workshop. One of the top priorities was the need to establish reinforcement requirements in masonry shear walls. At present, 90 percent of the masonry construction in the United States is unreinforced and is located in seismic zones 2 or below (relatively low seismicity on a scale of 1 to 4). While there was general agreement on the need to use reinforced masonry in high seismic risk areas (zones 3 and 4), and a good deal of ongoing research is focused on masonry construction for such

regions, there evolved a considerable divergence of opinion about whether the masonry in lower risk areas should be reinforced, and if so, what amount of reinforcement would be needed.

This project will establish a new test method that offers: loading of masonry walls in the reverse flexural mode typical of masonry pier elements in actual buildings; an accurate assessment of the forces transmitted at the specimen boundaries; a procedure that can be effectively applied to masonry having diverse composition, sectional configuration, and reinforcement arrangement; and a plan that readily lends itself to study the effect of oblique forces on shear wall strength.

PREPARATION OF THE AMERICAN NATIONAL STANDARDS INSTITUTE STANDARD A41, " REQUIREMENTS FOR MASONRY"

Felix Y. Yokel -301 -921 -3475
Structures, Materials and Safety Division

Sponsor: National Bureau of Standards

Present masonry standards are fragmented and sometimes contradictory and do not adequately reflect the state-of-the-art. This is especially true in view of recent developments, such as the revision of seismic design standards and the introduction of ultimate-load designs for concrete. A new comprehensive masonry standard is urgently needed. The overall goal of this project is to eventually introduce a single comprehensive national standard for masonry through the American National Standards Institute, as Standard A41.

As a first step, the present Standard A41, which is outdated, is being revised and re-issued as an empirical standard (at least 80 percent of all masonry construction is not engineered and thus would fall under the provision of the empirical standard).

The approach is to provide CBT sponsorship until the empirical standard is adopted, and to subsequently act as a catalyst to bring resources from within the profession to adopt a standard for engineered masonry.

FUNDAMENTAL MECHANISMS OF WIND LOADING

Richard D. Marshall -301 -921 -3475
Structures, Materials and Safety Division

Sponsor: National Bureau of Standards

This project will investigate the intensity and spatial extent of wind pressure fluctuations acting on buildings. It also will develop simplified equivalent loadings that can be used in building codes and standards. The project will involve the use of wind pressure measurements obtained on full-scale buildings over the past several years and from recent wind tunnel studies, the validity of which has been established through correlation with full-scale measurements. Design wind speeds will be reassessed for the purpose of ensuring consistent levels of structural safety.

In the past, the American National Standards Institute (ANSI) Committee A58.1, "Building Code Requirements For Minimum Design Loads In Buildings and Other Structures" has relied heavily on the Center

for technical support. This support has included research into those areas which have not received the attention of trade associations and which are not sufficiently basic in nature to merit the support of the National Science Foundation. Because some model building codes have expressed specific reservations about provisions of the ANSI Standard A58.1-1972, which relate to localized loads on building elements, it is important that a reassessment of tributary loadings be carried out.

HIGH WIND STUDY FOR DEVELOPING COUNTRIES

Richard D. Marshall -301-921-3475
Structures, Materials and Safety Division

Sponsor: Agency for International Development

Research is needed to supplement what is known about the effects of wind on low-rise buildings. Existing design criteria for wind loads do not make adequate provisions for fluctuating wind pressures along the edges of roofs and walls, (extreme negative pressures in these regions being one of the primary contributors to building damage). This research effort has great potential for reducing wind damage (thereby greatly reducing loss of life and property, the disruption of development, and the costs of disaster relief) in the United States and in other areas of the world.

Beneficiaries of this research will be the design profession, regulators, researchers, financial lending institutions, manufacturers, and building owners and users. Technical data resulting from this study will be made available to the American National Standards Institute A58.1 subcommittee, "Minimum Design Loads in Buildings and Other Structures." The project's results have provided the first step in revising the Philippine National Building Code, Section 2.05, "Wind Pressure." Project results also will be considered as building codes in the Caribbean area are revised. A 5-volume report, *Building To Resist the Effect of Wind* (Building Science Series 100), and a user-oriented report, *43 Rules: How Houses Can Better Resist High Winds* (NBSIR 79-1197) will be published in the Spring of 1977.

ADMINISTRATION OF THE SECRETARIAT, THE AMERICAN NATIONAL STANDARDS INSTITUTE A58, " BUILDING CODE REQUIREMENTS FOR MINIMUM DESIGN LOADS IN BUILDINGS AND OTHER STRUCTURES"

Robert A. Crist -301-921-3471
Structures, Materials and Safety Division

Sponsor: National Bureau of Standards

A measure of today's national need is the flow of inquiries to the American National Standards Institute (ANSI) and the Center for Building Technology (CBT) regarding the use of the present standard for loads on buildings. It is obvious that a consistent set of design loads should be used and that a particular structure in a particular geographical location should be able to withstand the same load on it regardless of which code is applied. This is not the case today. A primary problem that the committee is directly addressing is the confusion in the use of load factor design, which has resulted in different load factors being used for different structural materials.

The CBT Secretariat also includes the USA Technical Advisory Group Administration for the International Organization for Standardization Committee TC-98, "Bases for the Design of Structures." The Secretariat responsibilities will be maintenance of the current Standard, ANSI A58.1-1972; formulation, organization, and coordination of the A58 Committee; and coordination of revisions to the current standard (estimated for completion by 1980).

IMPROVEMENT OF HONEYCOMB CORES

Thomas W. Reichard -301-921-3475
Structures, Materials and Safety Division

Sponsor: Department of the Army Natick Laboratories

All branches of the military use lightweight, air-transportable, rigid structures that serve as combination shipping containers and shelters for many types of tactical and life-support services. The use of these shelters has increased so rapidly in recent years that life-cycle costs have become a major economic factor. These shelters are fabricated from either paper honeycomb core or foamed plastic sandwich panels. The shelters however suffer from any of four frequent defects: improper panel fabrication procedures (adhesive bonding), inadequate performance of the core, poor choice of materials, or inadequate design. To solve these problems, the Center is undertaking a three-phased study that will: establish a technical data base for improved honeycomb core criteria and companion test methods; evaluate trial manufacturing runs of honeycomb cores made to the improved requirements; and help the industry establish improved quality-control procedures for all honeycomb sandwich panels.

EVALUATION OF MOBILE SHELTERS

James R. Shaver -301-921-3475
Structures, Materials and Safety Division

Sponsor: United States Air Force

The Air Force accepts its mobile shelters based on the results of structural tests that are believed to simulate the transporation and operational loads that the shelters experience during their service lives. However, this procedure can lead to shelters that are over-designed with respect to certain service loads; it can also be costly when the shelter fails to pass some of the required tests. In this project, structural models are developed to predict the response of particular shelters to loads that the shelters will experience in use. Field tests are then used to prove the validity of the models. The models in turn will lead to better shelter designs.

FIRE-RESISTANT STRUCTURAL DESIGN

Bruce R. Ellingwood -301-921-3475
Technical Evaluation and Application Division

Sponsor: National Bureau of Standards

Fire resistance and reserve load-carrying capacity for reinforced concrete structural members exposed to severe fires is an important engineering problem in view of the economic and human costs involved. Fire resistivity of structural members is currently determined by evaluating their behavior when subjected to a standard American Society for Testing and Materials fire test. This may be quite costly. Previous research by the Center has produced a computer program that

numerically simulates the structural response to the standard fire furnace test of a simply supported beam.

In this project, the limiting states of structural performance to which the design criteria are directed will be identified. Although current practice is to determine fire resistivity on the basis of endurance, other criteria may be more relevant, such as reserve load-carrying capacity. Moreover, the occurrence, duration, and severity of fires are random events, and many of the material properties and design parameters are random variables. In view of this, the development of design aids should have a statistical basis. Accordingly, existing data on fire performance of structural members will first be examined to determine variability of behavior and correspondence, if any, with behavior in the laboratory. Correlation of member performance to current fire design criteria will be established, and factors over which the designer has some control and which significantly affect performance in fires will be identified.

FIRE ENDURANCE OF FLOOR CONSTRUCTIONS

Jin B. Fang -301 -921 -3461
Center for Fire Research

Sponsor: Department of Housing and Urban Development

Fire statistics indicate that basement fires are responsible for approximately 26 percent of the total residential fire fatalities, exceeded only by fires originating in the family or living rooms. The problem is that unprotected loadbearing structural elements may collapse or burn through. This project, with technical support from the National Bureau of Standard's Center for Fire Research, will establish a realistic research-based foundation for fire growth in residential basements. The test procedure to be developed will be based on measurements from full-scale fire tests using actual representations of residential furnishings, rather than extrapolated estimations based on conditions existing many years ago. By performing the basic research on fire growth, followed by evaluation of typical protected and unprotected floor constructions, and by supporting these with analytical calculations, the ultimate recommendations will be technically sound and adaptable to many alternate types of construction. Project results will be given to the Department of Housing and Urban Development in the form of reports with recommended criteria; to professional engineers, such as the American Society for Testing and Materials and the National Fire Protection Association Fire Test Committees, in terms of test procedures; and to code officials in the form of recommendations for safety.

Disaster Mitigation

BUILDING PRACTICES TO REDUCE DISASTER LOSSES

Charles G. Culver -301-921-3126
Office of Housing and Building Technology

Sponsor: National Bureau of Standards

This is a continuing project to improve the way buildings are built -- specifically to help them survive floods, hurricanes, tornadoes, and earthquakes. The program results in design requirements and standards that become a part of professional practice. The seismic design provisions being developed as part of the program will reduce human and property loss due to earthquakes. The General Services Administration has used a method developed by the Center to establish their hazard assessment computer program. Also under this project, post-disaster investigations are conducted after earthquakes, tornadoes, hurricanes, and other extreme or unusual loading conditions, such as construction failures.

FORMULATION OF SEISMIC DESIGN PROVISIONS

James R. Harris -301-921-3361
Office of Building Standards and Codes Services

Sponsor: National Science Foundation

The purpose of this project is to facilitate the development and use of the seismic design provisions that are currently being developed for the Center's Disaster Mitigation Program by the Applied Technology Council (ATC). This is a collaborative effort with Carnegie-Mellon University.

The seismic design provisions address the earthquake problem on a national basis with inputs from research, design and industry groups. In addition, the proposed provisions are more comprehensive than existing provisions; they include requirements for architectural and mechanical/electrical components as well as for structural design.

This project assists ATC by making recommendations to them concerning the clarity, completeness, consistency and accessibility of the provisions. The project assists the implementation and use of the provisions by publishing a formal documentation of the logic of the written provisions and alternate organizations of the provisions for special interest groups. The recommendations, formal documentation, and alternate organizations are based upon a systematic analysis incorporating decision tables, topological networks, and hierarchical classifications. This project, then, is designed to facilitate the goals of earthquake disaster mitigation by assuring that the design provisions produced are usable for building regulations.

EARTHQUAKE-RESISTANT MASONRY

Robert A. Crist -301-921-3471
Structures, Materials and Safety Division

Sponsor: National Science Foundation

Research projects on earthquake resistant masonry construction are now in progress nationally and internationally. Researchers, code and standards writers, designers, and the construction community need to be informed of the new information and have access to it. Design criteria for masonry structures are technically lagging by 10 to 20 years behind other

materials such as wood, reinforced concrete, steel, and aluminum. The development of improved design criteria for masonry is a significant component of the disaster mitigation program. The Center ran a week-long conference on the topic at Boulder, Colorado, last year. The proceedings of that meeting are available to designers concerned with seismic loads and to the professional community in general.

Architectural Research

ARCHITECTURAL PERFORMANCE FACTORS IN ENERGY CONSERVATION

Edward A. Arens -301-921-3595
Building Environment Division

Sponsors: *Department of Housing and Urban Development, Energy Research and Development Administration*

This project will determine the energy consumption implications of architectural design, particularly design that adapts to and capitalizes on its surrounding climate, for input to the development of energy budgets for buildings. CBT researchers will study the range of energy use and the mathematical functions describing these design factors: siting relative to terrain and other buildings; orientation; envelop (walls, windows, doors, roof, floor); thermal mass, interior proportions, and space utilization. The results of this work -- on single-family residences and on buildings -- will serve as input to proposed building energy performance standards.

ARCHITECTURAL ASPECTS OF WINDOWS

S. Robert Hastings -301-921-3595
Technical Evaluation and Application Division

Sponsor: *National Bureau of Standards*

Until recently, the energy consumption of competing architectural designs were of little concern. The mechanical and illumination systems could always be designed to compensate accordingly. The rapid escalation of energy costs has changed this situation. It is now important that architectural design strategies that will conserve energy be identified and that lighting, cooling, heating, and ventilation load calculations be sensitive to such design subtleties. Windows are a critical consideration because they may be responsible for up to 40 percent of a building's heating and cooling loads, or they may actually reduce these loads. This project will identify energy conserving design strategies for windows, evaluate their energy effectiveness, and assess non-energy consequences of strategies to conserve energy. In addition, this project will assist in the synthesis of architectural design strategies from the thermal, psychological, and economic constraints. A set of interdisciplinary guidelines will then be published and a Federal workshop on window research will be conducted.

HUMAN BEHAVIOR IN FIRES

Fred I. Stahl -301-921-3595
Technical Evaluation and Application Division

Sponsor: *Department of Health, Education and Welfare*

Each year, a great many people die or are injured in fires. And among the elderly and infirm the statistics are, not surprisingly, especially high. Thus, the primary aim of the project is to develop a model of occupant behavior in fires in health-care facilities, for the purposes of: exposing and estimating critical parameters and relationships, guiding future research and data collection, and constructing tools with which architects can predict the impact of design decisions upon occupants' ability to escape, and otherwise protect themselves, during building fires. As a first step, the Center is developing a computer simulation with the emphasis on human behavior. Peripheral systems such as fire/smoke migration or computer-graphics are important to the overall research program. The simulation shall be designed to be compatible with

existing threat-migration and graphics routines. This project will provide an opportunity to explore the problems of simulating human responses to fire events much more systematically, in greater depth, and solely in relation to health-care facilities. The end product will be reports that document the systematic development of the simulation model as well as the operational characteristics of the simulation program.

ARCHITECT-IN-RESIDENCE

Porter Driscoll -301 -921 -3704
Technical Evaluation and Application Division

Sponsor: National Bureau of Standards

To strengthen the link between the design professions and the building research community, the American Institute of Architects and CBT jointly select a practicing architect to work in the CBT setting for 1 year. This is the third year of the project. In previous years, the architects have worked on solar energy, natural lighting, and acoustics. This year, the architect will concentrate on the effectiveness of the way CBT research is communicated to working architects. The immediate beneficiaries of this project will be the architects of the United States who will be encouraged to interact with the National Bureau of Standards through their professional society, the American Institute of Architects. This project is supportive of other National Bureau of Standards activities, particularly other architectural projects and the *Architectural Graphic Standards* Task Force.

POST-OCCUPANCY EVALUATION OF GOVERNMENT BUILDINGS

Arthur I. Rubin -301 -921 -2177
Technical Evaluation and Evaluation Division

Sponsors: Government Services Administration,
National Institute of Health

In 1974, the Arts Endowment Federal Architecture Project recommended that Federal buildings specifically consider human needs. One of their recommendations: "Post-occupancy evaluation of buildings should include an analysis on how buildings meet community and user needs." In addressing the subject of research it states: "What can safely be said is that there is not enough architectural research and development, in or out of government, and more specifically, not enough dealing with the ways that buildings relate to their users." The report underlines the Endowment's responsibility for upgrading the design function for federal buildings through "extending the concerns of Federal design excellence to government personnel, to design consultants and to the general public." The post-occupancy evaluation project is a response to these issues. The central purpose of this project will be to develop a preliminary set of measurement procedures for post-occupancy evaluation.

A building will be chosen from each participating Federal agency and will be evaluated from one or two environment-behavior aspects (direction-finding, auditory privacy) of interest to the researchers and to the agency. Since each building will have different activities, the aspects studied and the methodologies used can be evaluated across more than one building type.

Safety

SAFETY IN BUILDING EXCAVATION

Felix Y. Yokel -301-921-3475
Structures, Materials, and Safety Division

Sponsor: National Bureau of Standards

Under this project, the Center will develop a measurement system and install it in braced excavations to determine the forces acting on braces, their variability, and their relation to displacements. The measurements will then be used to verify CBT's analytical methods for evaluating the stability of excavations. The technical challenge of the work is to develop a reliable measurement system for determining the pressures acting on excavation bracing and the displacements experienced by the bracing system as the excavation proceeds, and to later use these measurements to determine actual pressure and displacement and their correlation with the type of bracing system used.

SAFETY IN CONCRETE BUILDING CONSTRUCTION

Hai S. Lew -301-921-3852
Structures, Materials, and Safety Division

Sponsor: National Bureau of Standards

This project is concerned with criteria and standards for safe design, erection, and removal of formwork and shoring during concrete construction. The first phase includes a study of strength gain characteristics of concrete and a determination of the effects of shoring imperfections. Previous research has shown that the magnitude of load imposed on the structure during construction is sometimes greater than the load that the finished structure is designed to safely support. An analytical procedure in the form of a computer model will be developed to study the parameters that affect the distribution of loads between the formwork system and the structure. The technical information developed from this project will be applied to industry, through the American National Standards Institute, and to mandatory Federal standards through the Occupational Safety and Health Administration. It is expected that the project's results will significantly improve safety in construction.

ESTIMATING THE STRENGTH OF CONCRETE

Hai S. Lew -301-921-3852
Structures, Materials, and Safety Division

Sponsor: National Bureau of Standards

One of the most critical judgments to be made in concrete construction is the decision to remove the formwork and shoring. Most of the serious accidents in concrete construction occur when formwork or shoring is removed too soon. However, recent research at the Center indicates that the strength of concrete can be reliably estimated using a factor combining the curing temperature and the curing period. This factor is termed the maturity of the concrete. This project will develop and test an electronic measurement device that will automatically and continuously compute and display the estimated early-age concrete strength, using the maturity concept. This instrument, if shown to be reliable, would be useful to the construction industry.

PARTICIPATION IN THE AMERICAN NATIONAL STANDARDS INSTITUTE COMMITTEE A10, "SAFETY REQUIREMENTS FOR CONSTRUCTION"

James O. Bryson -301-921-3851
Structures, Materials, and Safety Division

Sponsor: Occupational Safety and Health Administration

Voluntary standards committee work for improved safety standards is a continuing effort. New standards are developed when new or different procedures are put into use, and old standards are revised when new and better information becomes available. In this regard, this program is a continuing one. The Center will assume the leading role in developing and providing the basic technical information for updating safety standards, particularly in the area of concrete construction, trenching, and excavation. CBT will participate in subcommittee activities and contribute to updating standards in areas where new research information is available or where studies are currently underway. Reports will be prepared on critiques of specific standards. CBT is also working directly with the Occupational Safety and Health Administration, the American Federation of Labor-Congress of Industrial Organizations (Building and Construction Trades Department), Associated General Contractors, and others on matters dealing with this problem.

SLIP RESISTANCE

Sanford C. Adler -301-921-3852
Technical Evaluation and Application Division

Sponsor: National Bureau of Standards

The nearly 10,000 deaths and 1 1/2 million disabling injuries caused by slips and falls in American homes each year (as reported by the National Commission on Product Safety) point up the need for improvements in slip-resistance measurements. Work began on these improvements last year, when the Center developed the NBS-Brungraber portable slip tester. The tester provides highly repeatable and accurate results; is usable under wet or dry, laboratory or field conditions; accepts sensor materials representative of bare or shod feet; and can be easily and reliably calibrated. The tester has been incorporated in a draft American Society for Testing Materials standard for slip-resistance of bathtub and shower surfaces.

This year, the research has three goals: to establish a standardized, quantitative test procedure; to establish a data base for flooring and shoe sole materials to recommend acceptable, quantitative levels of slip-resistance; and to study the mechanism of slips and falls.

STAIR SAFETY

John C. Archea -301-921-3595
Technical Evaluation and Application Division

Sponsor: National Bureau of Standards

The goal of the stair safety project is to reduce the frequency and severity of stair accidents. These accidents cost the U.S. public over a billion dollars annually in medical costs alone. Key objectives are to substantiate stair safety requirements and to provide and deliver stair safety information for use by researchers, building code officials, model building code

organizations, government agencies with building regulatory functions, architects, other building designers, and building managers. This year the project will publish the reports *Stair Safety Performance Requirements for Retrofitting Buildings*, and *Stair Safety Performance Requirements for New Construction*. A stair safety design guide for architects and a technology transfer system also will be developed.

SECURITY SYSTEMS

Thomas W. Reichard -301-921-3475
Structures, Materials, and Safety Division

Sponsor: National Bureau of Standards

This project is to provide performance criteria and test methods for evaluating the resistance of residential and light commercial door and window assemblies to forced entry. In the past, project staffers have instrumented typical doors, windows, and burglary tools, so that the actual forces imposed during a break-in could be measured. Technical data then were used in developing criteria and test methods. Proposed criteria for swinging door assemblies were delivered to the Bureau's Law Enforcement Standards Laboratory (LESL) and then submitted by LESL to the Law Enforcement Assistance Administration for promulgation as a voluntary standard (NILECJ-STD-0306.00). LESL also published a user-oriented brochure, *Home Security Starts at Your Door*, a free, illustrated folder covering doors, locks, frames, and hinges. Moreover, the technical and trade press have also published information regarding the door security standards. Proposed standards developed by the Center for windows and sliding glass doors also have been delivered to LESL and are being circulated for comment in both private and public sectors. The swinging door standard has been widely disseminated and has encouraged the upgrading of doors and locks by industry. The standard's minimum requirements have been incorporated in a model code (the Uniform Building Code) and the standard's test methods have been adopted by the American Society for Testing and Materials.

DOOR AND WINDOW SECURITY DEMONSTRATION

John S. Stroik -301-921-3595
Technical Evaluation and Application Division

Sponsor: Department of Housing and Urban Development

In an earlier project, the Center developed door and window security standards for the Department of Justice. In this project, the standards are being field tested in three public housing sites. The field test demonstration is recording the actual performance of specific door and window components to measure just how well they survive actual break-in attempts. The outcome of the project will be a set of specifications for bidding, installation, and maintenance of door and window components and assemblies built to door and window security standards for use by local housing authorities. Further, the study will develop

recommendations for changes in model building codes and the Department of Housing and Urban Development's Minimum Property Standards.

ELECTRICAL DISTRIBUTION SYSTEMS

Adolfo A. Camacho -301-921-3293
Building Environment Division

Sponsor: National Bureau of Standards

This project will identify the performance-oriented needs of electrical service systems in buildings. Its first step will be a state-of-the-art survey and review of existing codes such as the National Electric Code (NEC), standards such as those of the American National Standards Institute, and fire safety requirements such as those of the National Fire Protection Association (NFPA). The study will also identify technology gaps to improve performance from the building service entrance to point of use, with respect to fire safety, shock prevention, and efficient distribution of energy. The findings of the study will contribute to NFPA 70 and NEC standards.

Mobile Homes

ENERGY CONSERVATION IN MOBILE HOMES

Bradley A. Peavy -301-921-3503
Building Environment Division

Sponsor: National Bureau of Standards

This project includes the instrumentation and study of the thermal performance of a new furnished mobile home, built to the American National Standards Institute A119.1-1975, Mobile Homes Standards (with foam insulation in the walls and under the floor). The outcome of the work will be methods of factory testing mobile homes to determine air infiltration rates and to identify areas of excess air leakage. Also, predicted versus actual energy use will be compared under simulated weather conditions to develop energy budget figures for mobile homes. Moisture condensation problems in the mobile home envelope also will be studied. Emphasis will be placed on developing criteria for the installation of water vapor barriers and for ventilation control equipment.

PARTICIPATION IN THE AMERICAN NATIONAL STANDARDS INSTITUTE COMMITTEE A119, "MOBILE HOMES AND RECREATION VEHICLES"

James H. Pielert -301-921-3447
Office of Building Standards and Codes Services

Sponsor: Department of Housing and Urban Development

As part of its role in transmitting the results of its mobile home research, the Center takes an active part in the American National Standards Institute (ANSI) Committee A119, "Mobile Homes and Recreation Vehicles." There are presently on-going Institute for Applied Technology mobile home research projects in the areas of fire safety, wind resistance, thermal performance, and performance evaluation. CBT work in energy conservation can have a direct economic impact on mobile home consumers as well as impacting a national problem. Work in these areas needs to be rapidly incorporated into mobile home standards. The project's overall goal is being met by attendance at meetings of the ANSI Correlating Committee, the Mobile Home Sectional Committees and the Mobile Home Installation Sectional Committee; coordinating the National Bureau of Standards staff input to the standards development deliberations; formulating ballot responses; and supporting the Federal Mobile Home Standard.

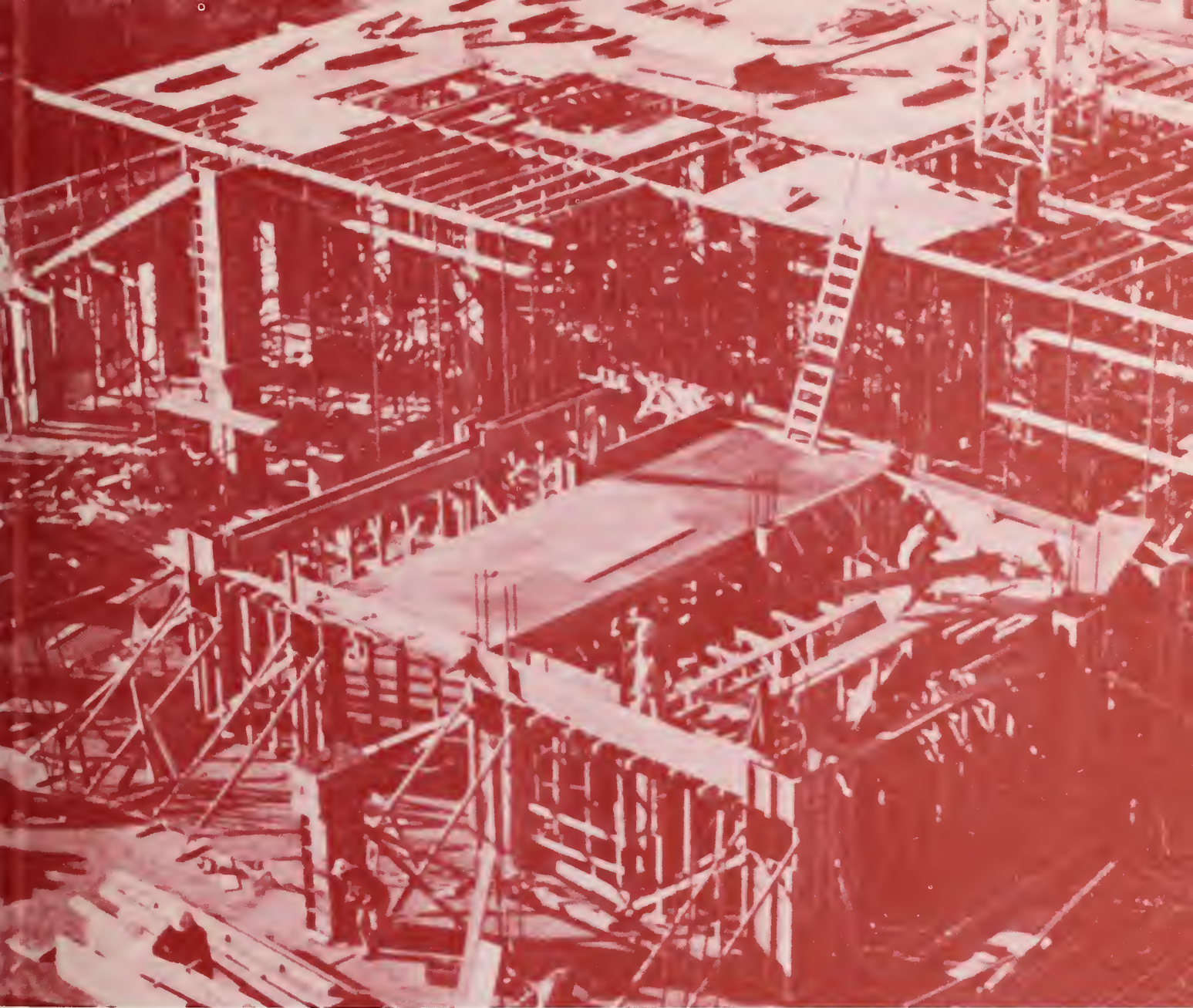
WIND FORCES ON MOBILE HOMES AND ANCHOR SYSTEMS

Richard D. Marshall -301-921-3475
Structures, Materials and Safety Division

Sponsor: Department of Housing and Urban Development

This project involves full-scale studies of wind forces and the response of a mobile home to these forces. A 3.7 by 18.3m (12 by 60 ft) unit will be fully instrumented to measure internal pressures, external surface pressures, lift and drag forces, and racking deformations. Corresponding measurements of the mean and fluctuating components of the oncoming wind also will be measured. Finally, the data will be reduced to dimensionless coefficients and applied to appropriate reference wind speeds to obtain design loads in terms of equivalent static loads.

A final report will be prepared which fully describes the experimental setup, the experimental techniques used, the test results and results of the data analysis. Finally, recommendations will be developed for the next revision of those sections of the Department of Housing and Urban Development's Federal Mobile Home Construction and Safety Standards dealing with wind loads.



Codes and Standards

BUILDING STANDARDS DEVELOPMENT

James H. Pielert -301-921-3447
Office of Building Standards and Codes Services

Sponsor: National Bureau of Standards

It is important for the Center to encourage a unified building standards and codes system because of the added economic burden on builders, regulators, and consumers caused by a fragmented regulatory system. The technical content of national building regulations also needs to be harmonized with international regulations. The performance concept is an important vehicle for accomplishing this goal.

The project's primary objective is to transfer the results of research programs into the building community as well as to identify research areas where CBT could effectively work. A secretariat has been provided to CBT's present unit within the Bureau, the Institute for Applied Technology (IAT)/Building Standards Council (BSC). This covers scheduling of meetings, preparation of agenda and the development of special reports. Objectives of the IAT/BSC are to develop policy on building standards issues and to coordinate standards activities which overlap various IAT units. High-priority building standards activities funded under separate projects will be monitored to improve their impact on the standards development process. These include: the American National Standards Institute (ANSI) A58 "Design Loads in Buildings;" ANSI A41 "Masonry; Foundations and Excavations" (formerly ANSI A56); the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 100 "Energy Conservation in Existing Buildings;" ANSI A40 "National Plumbing Code;" ASHRAE 90-75 "Energy Conservation in New Buildings;" Solar Energy Standards; American Society for Testing and Materials C16 "Thermal Insulation;" Secretariat for Building Safety Communications Standards; ANSI A10 "Safety in Construction;" and ANSI A119 "Mobile Homes." Each of these standards activities is related to ongoing research in CBT.

CBT is also represented at the International Standards Organization Divisional Council for Building and Construction, which has responded to a United Nations request for technically coherent international standards. This response includes a plan to develop international standards describing methodology, terminology, and format for rewriting building regulations in performance terms.

BUILDING CODES SERVICES AND IMPROVEMENT

James M. Hicks -301-921-3146
Office of Building Standards and Codes Services

Sponsor: National Bureau of Standards

The CBT building research can reach code and regulatory agencies with a minimum of delay by working through established groups such as the model codes, the National Conference of States on Building Codes and Standards, the American Major City Building Officials, the Council of American Building Officials, etc. This will be accomplished by the distribution of publications and representation at important meetings,

participation on advisory committees of various model code groups, maintenance of a building code file on current regulations, and other activities for advancing the trend toward greater uniformity between building codes. The model code change hearings and annual meetings represent unique opportunities for the dissemination of CBT research. Prior to these meetings, the proposed code changes will be reviewed for relevance to on-going National Bureau of Standards research. Where appropriate, technical input will be provided through written testimony or through attendance at the hearings by CBT staff.

NATIONAL CONFERENCE OF STATES ON BUILDING CODES AND STANDARDS

James H. Pielert -301-921-3146
Office of Building Codes and Standards Services

Sponsor: National Bureau of Standards

The building regulatory system, increasingly a State function, represents the public interest in the design, construction, and operation of the built environment. The National Conference of States on Building Codes and Standards (NCSBCS) is a means by which the Center's research can reach the regulatory agencies with little delay. NCSBCS is a vehicle for helping the Center identify building research needs because State regulatory agencies are in direct daily contact with building users and constructors. This is an effective means for cooperative participation of all levels of government in reaching decisions regarding supportive technical assistance, research, and finance.

This year, the Center is providing NCSBCS with continuing technical assistance; providing a senior technical advisor to its Board of Directors; providing technical support to participating organizations of NCSBCS; and providing liaison between the States, the codes and standards generating organizations, and the Federal Government. The Center also is giving direct technical input to NCSBCS standing committees.

RESEARCH CONFERENCE ON THE BUILDING REGULATORY PROCESS

Patrick W. Cooke -301-921-3361
Office of Building Codes and Standards Services

Sponsor: National Bureau of Standards

This annual conference is intended to inform and assist decision-makers in the regulatory area by reporting on building regulatory developments that advance or retard technological change. Why is this necessary? Because regulatory policy is too often made and enforced without the benefit of objective knowledge of the impacts of those policies on the building community and whether those policies are achieving the desired effect. Last year, a Center for Building Technology/National Conference of States on Building Codes and Standards Joint Conference on Research and Innovation in the Building Regulatory Process was held at Providence, Rhode Island. Proceedings of the sessions, including the 26 papers presented, are being published. A *Directory of Current Research on the Building Regulatory Process* also will be

published, as will the proceedings of a workshop on *Innovations in Building Regulatory Agency Management and Procedures* held in Santa Fe, New Mexico.

COMPILATION OF THE LABORATORY EVALUATION AND ACCREDITATION PROGRAM

Patrick W. Cooke -301 -921 -3361
Office of Building Standards and Codes Services

Sponsor: National Bureau of Standards

It is not enough for the construction industry to evaluate and approve its buildings and the materials used in them. Steps must also be taken to certify the laboratories where building research is undertaken. Thus, for the National Conference of States on Building Codes and Standards (NCSBCS), the Center began a Laboratory Evaluation and Accreditation Program (LEAP) to develop criteria to determine the capabilities of laboratories to perform engineering analysis, testing, and inspection.

The work uncovered a technical basis for the evaluation of laboratories that certify manufactured buildings, mobile homes, and building components. To date, the project resulted in the creation of two voluntary consensus standards generating committees (the American Society For Testing and Materials E-32, "Criteria for Evaluating Agencies Concerned with System Analysis Testing and/or Compliance Assurance of Manufactured Buildings" and E-36, "Criteria for the Evaluation of Testing and/or Inspection Agencies,") to further process the LEAP documents into final standards for national use. Further, a joint cooperative effort was undertaken in Massachusetts to demonstrate the impact of such a program on the building regulatory processes of the Nation. The LEAP final document to be developed this year will regulatory agencies, manufacturers, and users of buildings and building products.

COORDINATED METRIC DIMENSIONS FOR BUILDING

Ward V. Buzzell -301 -921 -3146
Office of Building Codes and Standards

Sponsor: National Bureau of Standards

This project provides research and technical studies as a basis for assisting all segments of the building community (including governmental agencies) in the development of an acceptable national program of metrication and dimensional coordination. The project produced NBS Technical Note 915, *Metrication Problems in the Construction Codes and Standards Sector* and a select bibliography on the subject. The Center accepted the role of secretariat for two sectors of the Construction Industries Coordinating Committee of the American National Metric Council and provided liaison with the International Standards Organization and with many industrialized nations. Late in the year the Center obtained the consulting services of the Assistant Secretary for Housing Research, Australian Department of Environment, Housing and Community Development.

While this project is targeted to benefit the building community as a whole, its major benficiaries

will be those organizations and governmental agencies involved in either the promulgation or the administration of building standards and codes. However, much of the research results will be used by the design and engineering members of the community, both those who are concerned with the design and planning of products/materials and assemblies and those concerned with total structures.

NATIONAL INSTITUTE OF BUILDING SCIENCES: TECHNICAL SUPPORT

James G. Gross -301-921-3447
Office of Building Standards and Code Services

Sponsor: National Bureau of Standards

The National Institute of Building Sciences (NIBS) was established by Public Law 93-383. The Center's role is to provide technical services and technical studies to the Board of Directors of NIBS to assist them in organizing NIBS to develop, promulgate, and maintain nationally recognized performance criteria, standards, and other technical provisions. Studies will be conducted in the areas of: frequency and area of existing building standards in building regulation, existing usage of performance standards and criteria in building regulation and procurement, identification of technical issues and problem areas related to development of performance standards and criteria, and technical studies on preferred format of performance standards and criteria.

MODEL DOCUMENTATION FOR ENERGY STANDARDS

Patrick W. Cooke -301-921-3361
Office of Building Standards and Codes Services

Sponsor: Energy Research and Development Administration

Considerable impetus was given to the development of energy conservation standards by the passage of the Building Energy Conservation Standards Act of 1975, providing for development of component performance standards as well as building performance standards. This project will focus on the preliminary development of model documents, formats, and administrative approaches to building energy conservation. The development of such a system will consider and be based in part on existing regulatory programs and evaluation or approval systems.

PERFORMANCE STANDARDS FOR SPECIAL AND INNOVATIVE CONSTRUCTION

Thomas K. Faison -301-921-3231
Office of Housing and Building Technology

Sponsor: Department of Housing and Urban Development

Under this project, the Center for Building Technology is preparing a document on performance criteria and methods of evaluation -- to be used by the Department of Housing and Urban Development in their mortagage insurance program. In effect, these new standards will have national impact because they will be used as a supplement to the HUD Minimum Property Standards. As new materials or types of construction are submitted to HUD for acceptance, these new supplemental performance standards will be used in those cases where the traditional Minimum Property Standards prove to be inadequate.

A RISK-ANALYSIS APPROACH TO BUILDING SAFETY

Robert J. Kapsch -301-921-3447
Office of Building Standards and Codes Services

Sponsor: National Bureau of Standards

The network of building regulations, standards, and codes provides a certain level of safety for makers and users of buildings. However, there is little understanding of people's attitudes toward different types of building related risks, and there is no uniform set of information on costs and safety losses that can be used to assess building regulations. In effect, this situation could simply raise building costs without improving safety.

This project consists of four major steps. The first step is to extensively review the behavioral and economic literature to identify information, theory, and studies concerning attitudes toward building-related risks, and human response to risk. The second step is to collect and identify source data on safety losses and costs. The third step is to compare the economic and behavioral studies in step one and the information compiled in step two to identify problem areas and further research needs. The final step is to formulate a workable approach to decision-making that will relate levels of risk to performance-based safety criteria. This tool also will be used to assess present and proposed building regulations.

Housing and Building Technology

HOUSING TECHNOLOGY

Thomas K. Faison -301-921-3231
Office of Housing and Building Technology

Sponsors: National Bureau of Standards, Department of Housing and Urban Development

This project is an open-ended source of technical assistance to provide answers to problems related to solving the Nation's housing needs. Last year, for example, the Center for Building Technology sponsored a solar energy roundtable to bring consumer-oriented magazine editors together with Federal technical policy makers to discuss solar demonstration programs. The Center also helped the Department of Housing and Urban Development (HUD) in program development through project proposal generation and analysis of program opportunities and coordinated semiannual project reviews for HUD long-range research. The Center also participated in the generation of plans for the Solar Heating and Cooling (Residential and Commercial) National Program. Technical support on these and other like projects will continue this year. The results of the research will be available in Center and HUD documents as well as professional papers.

FEDERAL BUILDING TECHNOLOGY

Harry E. Thompson -301-921-3233
Office of Housing and Building Technology

Sponsor: National Bureau of Standards

This project is designed to promote building research within the Federal agencies, to coordinate Federal activity in building research, and to provide technology to support Federal building. These objectives are met by sponsoring monthly workshops on building technology for Federal representatives, participating in the Federal Construction Council meetings, disseminating research results and reports, maintaining liaison with other Federal agencies, developing new techniques for use by other agencies, participating in committees, seminars, and workshops, and maintaining a Federal building criteria reference service. In addition, a Federal Building Research Panel will be established this year to study the research needs of the Federal building community.

HOME IMPROVEMENT TECHNOLOGY

Harvey W. Berger -301-921-3281
Office of Housing and Building Technology

Sponsor: Department of Housing and Urban Development

This project will investigate the role of technology in conserving the Nation's existing housing stock through the improvement and encouragement of repair, replacement, and renovation. The project will begin with an assessment of the state-of-the-art in renovation, especially those techniques which have promise but which are not now being used. A further study of technological gaps will identify targets of opportunity as well as likely areas of innovation. Concurrent with this research will be a look at constraints to technology, such as building codes or high investment and retooling costs.

INTERNATIONAL BUILDING RESEARCH

Noel J. Raufaste -301 -921 -3106
Center for Building Technology
Headquarters

Sponsor: National Bureau of Standards

This project is a forum for researchers from CBT and foreign research organizations to exchange information and coordinate their research activities. The project responds to foreign requests for technical information on building technology, supports complementary building research activities, provides a mechanism to exchange technical staff, provides a means to participate in international conferences as members in international organizations, and provides technical assistance to developing countries. In the recent past, CBT has conducted international programs with Brazil, Jamaica, Canada, France, Japan, Philippines, England, and Egypt and has served on numerous international panels (such as the International Council for Building Research Studies and Documentation, International Organization for Standards, the International Union of Testing and Research Laboratories for Materials and Structures, and the International Institute of Refrigeration). This year such work will be expanded to cover cooperative research with Poland, Israel, and Spain, among other nations. The Center also publishes an annual report on its international activities.

PROGRAM EVALUATION AND PLANNING

Noel J. Raufaste -301 -921 -3106
Center for Building Technology
Headquarters

Sponsor: National Bureau of Standards

This project supports the evolution, presentation, and documentation of the National Bureau of Standards building science and technology program. Among other things, the project is the focus of activity for coordinating the preparation of the CBT 5-year research plan. The project aims to develop and update the impact of CBT research projects; fully develop CBT's communications with the building community; increase participation with other National Bureau of Standards units concerned with buildings; develop the Congressional budget narrative and the subcategory document; and publish guides for preparing manuscripts and visual arts. Overall, these tasks assist CBT in reaching its institutional goals of a better built environment.

BUILDING TECHNOLOGY INFORMATION

Noel J. Raufaste -301 -921 -3106
Center for Building Technology
Headquarters

Sponsor: National Bureau of Standards

Information is the Center's ultimate product. This project is aimed at effective delivery of that product through skillful dissemination techniques and an understanding of the information needed by the building community. To this end, the Center has established a multidimensional information program. It broadcasts research findings, accommodates specific inquiries, and interacts with the building community through liaison activities with building groups, hosts tours and conferences at the Bureau, and participates at select meetings and conventions of building organizations. All this permits a two-way information flow; feedback

assists the information program in meeting the needs of the building community's research, policy-making, application, and consuming sectors. Recent productions were three companion reports, *Center for Building Technology: A Perspective*, which presents an overview of the Center's status and prospects; *Building Technology Project Summaries*, which summarizes the Center's research activities during 1975; and *Building Technology Publications*, a cumulative listing of all the Center's publications over the decade; brochures on select Center building research activities, and a draft report scheduled for printing in the Spring of *1978*, *History of Building Research at the National Bureau of Standards, 1968 - 1974*.

COOPERATIVE TRAINING PROGRAM WITH BRAZIL

Thomas K. Faison -301 -921 -3231
Office of Housing and Building Technology

Sponsor: Agency for International Development through State of Sao Paulo, Brazil

This project is a cooperative one between the Center and the Institute for Research Technology (Instituto de Pesquisas Tecnologicas, IPT), Brazil. It provides for IPT trainees to work on ongoing Center studies. A recent trainee worked on, among other things, performance criteria for windows, which will become the basis for similar Brazilian Standards. This year's three trainees will work in the areas of plumbing, electrical research, and materials durability. Center staffers also helped form a team of specialists within IPT to address the total performance of buildings.

TECHNICAL AND SCIENTIFIC SUPPORT TO THE TRI- SERVICES COMMITTEE

Harry E. Thompson -301 -921 -3231
Office of Housing and Building Technology

Sponsor: Tri -Services Committee of the Department of Defense

This project provides technical assistance and engineering support to assist the Tri-Services Committee of the Department of Defense in their building research and development activities. During FY77, nine areas of building research will be studied: earthquake-resistant design of masonry structures; reduced-sized venting; underground heat distribution; methods for reducing air leakage; building joint sealants; guidelines on foam polyurethane roofing systems; the effects of increased insulation on roofing performance; the cooling performance of fan-coil units; and polysyrene roof insulation. In addition, the Center's technical staff daily receive telephone inquiries requesting advice from the Tri-Services Committee. Typical of such requests are calls about material durability, heat transfer, insulation, underground pipe criteria, hydraulic criteria, paints, coatings, adhesives and structural related issues.

THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT LONG RANGE RESEARCH

Harvey W. Berger -301-921-3281
Office of Housing and Building Technology

Sponsor: Department of Housing and Urban Development

The United States has a continuing need for adequate, safe and durable housing at reasonable costs. To respond to this need, Congress, by legislation, assigns to the Department of Housing and Urban Development (HUD) certain regulatory and administrative functions in the housing field which require the application of housing technology and research capability. Since HUD has no laboratory facilities and its in-house technology based research capability is limited, they have turned to the Center for technical assistance and research support. The specific projects funded this year are summarized elsewhere in this report.

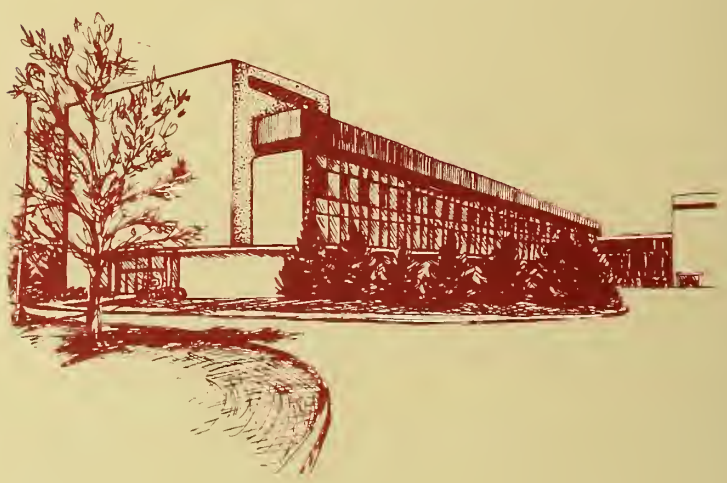
THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT QUICK RESPONSE STUDIES

Harvey W. Berger -301-921-3281
Office of Housing and Building Technology

Sponsor: Department of Housing and Urban Development

The Department of Housing and Urban Development (HUD) frequently receives inquiries or requests for information regarding problems in the building technology area. Many of these requests or problems require technical analysis or investigation. This project is designed to provide HUD with the capability of quickly bringing the Center's expertise in the building technology area to bear on these problems. Specific tasks may encompass such studies as conducting a fire test on a questionable material or assembly, a racking test on a panel wall, testing for arsenic leaching from preservative treated plywood, making air quality tests in homes where asbestos materials have been used, evaluating a component for durability, measuring the capability of an *in situ* brick testing device, writing a state-of-the-art report on plumbing trees, or develop criteria for hallway width.

Center for Building Technology
Institute for Applied Technology



U.S. DEPARTMENT OF COMMERCE
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Sidney Harman, Under Secretary
Jordan J. Baruch, Assistant
Secretary for Science and Technology

National Bureau of Standards
Ernest Ambler, Acting Director

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