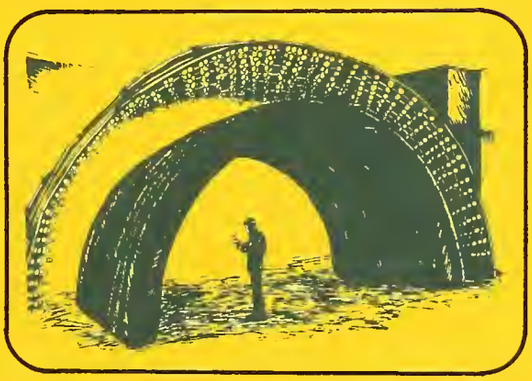
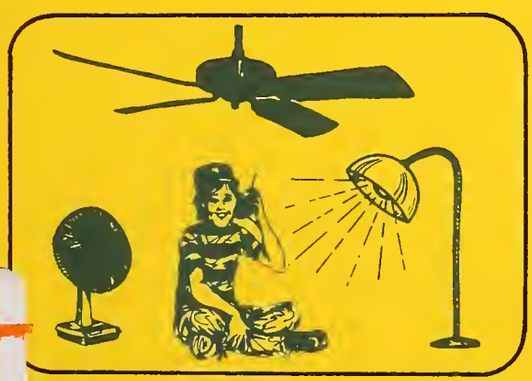
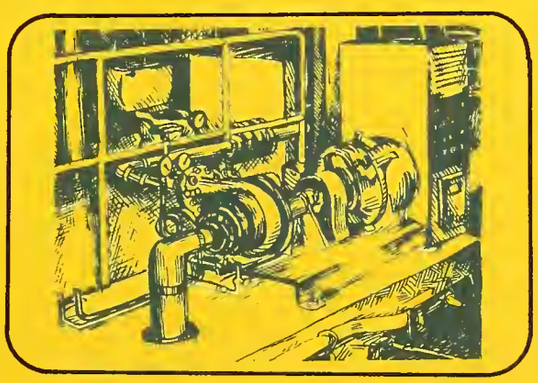
The CENTER for BUILDING TECHNOLOGY
INSTITUTE for APPLIED TECHNOLOGY
NATIONAL BUREAU of STANDARDS
DEPARTMENT of COMMERCE

building technology project summaries, 1975





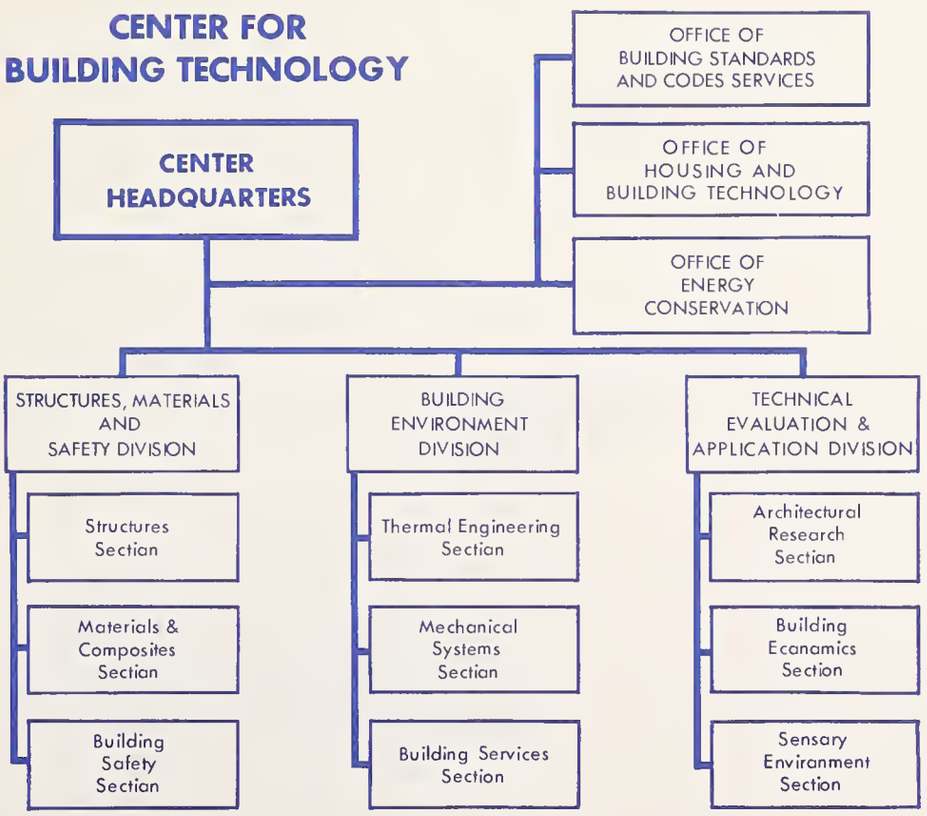


Foreword

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 while conserving building materials and energy. CBT's activities support the building technology program of the Federal, State and local government; assist design professions, building officials and the research community by developing design criteria that improve buildings; and assist manufacturers of building products by developing criteria for evaluating innovative building materials.

The report summarizes CBT's research for calendar year 1975. Each summary lists the project title, its progress, point of contact within CBT and sponsor. 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. Another document, *CBT Publications*, lists with abstracts and keywords, all reports published by CBT during the past decade.

The summaries presented in this report are arranged by subject-matter categories, such as Disaster Mitigation, 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:



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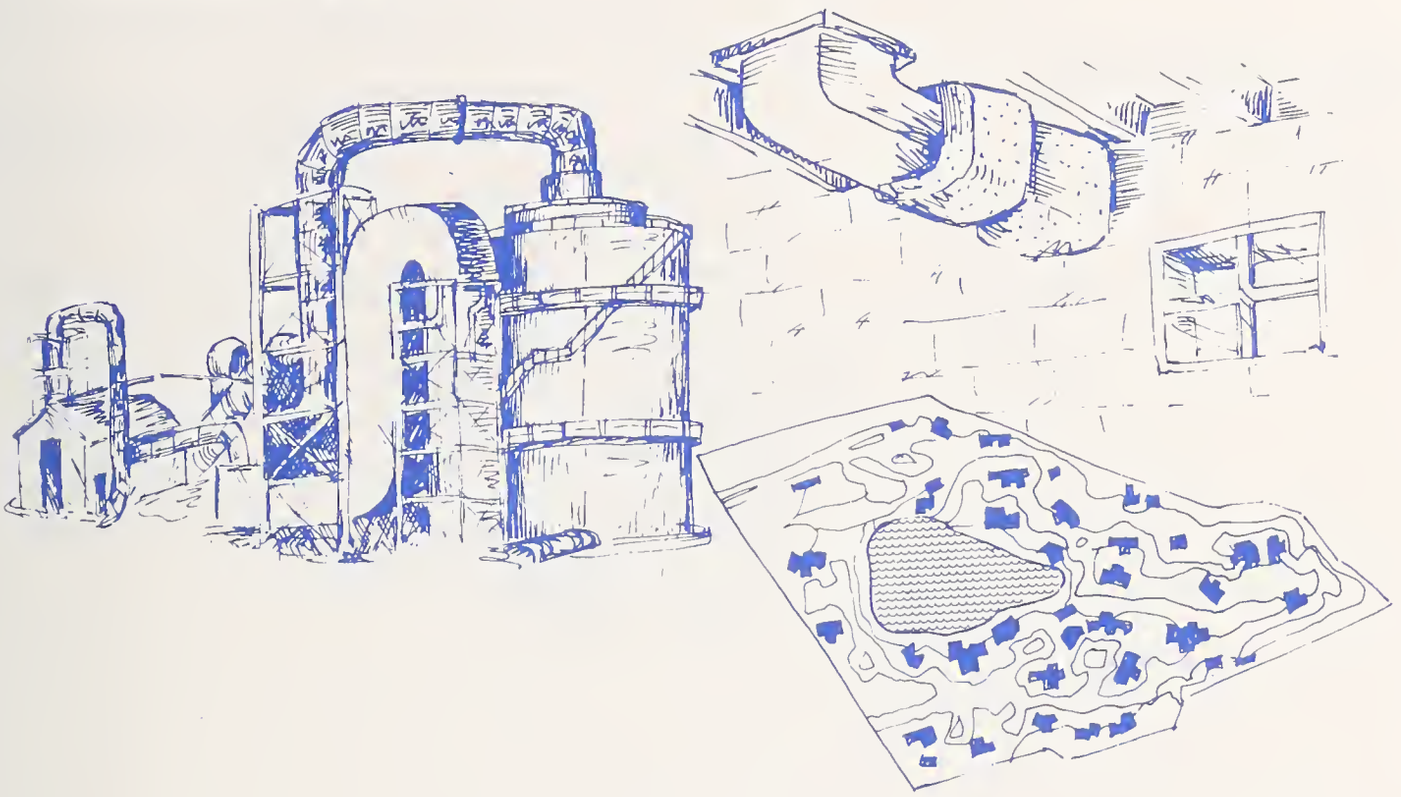
Energy Conservation



Energy Programs at the Center are centered in four areas, each presented in turn: energy savings in buildings; in industry; in newly planned communities; and in performance codes and standards.

ENERGY CONSERVATION PROGRAM

Jack Snell
Office of Energy Conservation - 301-921-3571

Sponsor - National Bureau of Standards

The National Bureau of Standards (NBS) energy conservation program involves coordinated efforts within the areas of buildings, community services, industry and standards carried out by many units within NBS and outside contractors. This project covers the overall planning, management, monitoring, and support functions of the energy conservation program office. The overall program plan and organizational framework were developed for management of the buildings and industry portions of the Center's energy program. Accomplishments include substantial staff support to the Federal Energy Administration, the Energy Research and Development Administration, and the Department of Housing and Urban Development in developing the FY76 energy conservation programs for these agencies.

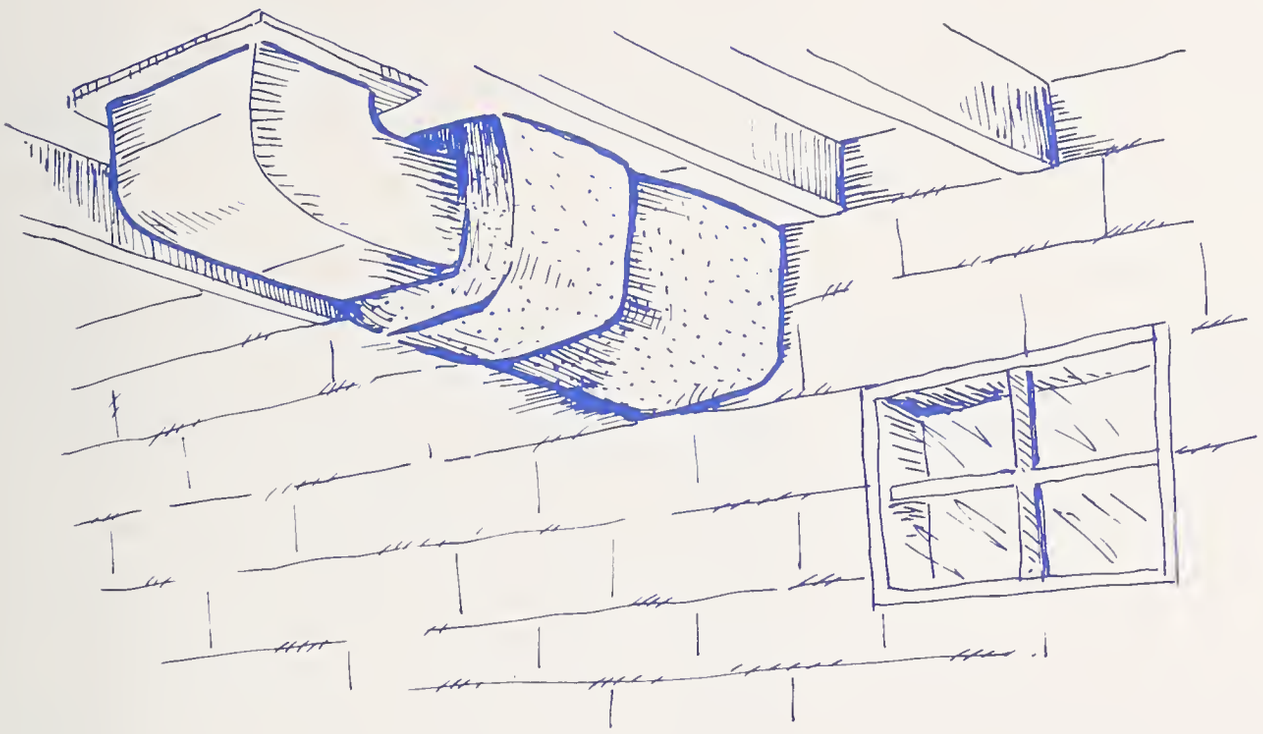
ENERGY CONSERVATION INFORMATION

Jack Snell
Office of Energy Conservation - 301-921-3571

Sponsor - National Bureau of Standards

To be most effective, research findings on energy conservation need to quickly reach those who may benefit from them. They also must be presented in an effective and usable form. This project supports preparation of a variety of publications to disseminate the findings of the National Bureau of Standards research. Inquiries for technical information are accommodated, and information brochures prepared. Liaison is being established and maintained with the university and academic community and with industry and professional groups to identify energy conservation needs and to foster the exchange of ideas and information. A series of issue papers will be presented and seminars involving leading academic and industry researchers will be supported.

Energy Conservation in Buildings



ENERGY CONSERVATION IN BUILDINGS

Heinz Trechsel
Office of Energy Conservation - 301-921-3892

Sponsor - National Bureau of Standards

This program involves coordinatcd efforts carried out by many units within the National Burcau of Standards and contractors. It supports the ovcrall building-related planning, management, monitoring, and support functions of the energy conservation program office. The Center is evaluating thc energy conservation in buildings program for FY77 and beyond, based on an analysis of future research needs and priorities. A systems study of energy balance in buildings, considering all the elements of energy gains and losses, is being conducted to determine those areas of technology requiring research which have the greatest potential for energy conservation both in the near and long term.

TECHNICAL AND MANAGEMENT SUPPORT TO FEDERAL ENERGY ADMINISTRATION

Heinz Trechsel
Office of Energy Conservation - 301-921-3892

Sponsor - Federal Energy Administration

The National Bureau of Standards (NBS) energy conservation in buildings program involves coordinated efforts within NBS, the Federal Energy Administration (FEA), outside contractors, and other agencies. Project activity includes detailed monitoring of the NBS research projects in the FEA-supported energy conservation in buildings program, milestone completion, and delivery of products. Major activities also involve developing and planning the research program and providing technical support to FEA for evaluation of research proposals, technical conferences, etc.

ENERGY STORAGE IN BUILDINGS

Joseph Chi
Building Environment Division - 301-921-3521

Sponsor - National Bureau of Standards

The goal of this program is to establish which energy storage techniques are most advantageous. The program is establishing criteria for incorporating energy storage systems into buildings, determining the potential of various types of energy storage systems, and developing test methods for evaluating energy storage systems. Some of the technologies to be evaluated are thermal storage (latent/sensible), flywheels, batteries, hydrogen, compressed air, magnetic and hydraulic.

The criteria to be developed will involve the determination of those parameters (i.e., energy density, specific energy, etc.) that are significant for evaluating the compatability of various energy storage systems with different types of buildings. It will also attempt to establish quantitative ranges within which the parameters should remain for each building type. These ranges will be established by a thorough analysis of energy demand in existing buildings.

GENERAL SERVICES ADMINISTRATION MANCHESTER BUILDING

Tamami Kusuda
Building Environment Division - 301-921-3501

Sponsor - Energy Research and Development Administration

The Center is assisting the General Services Administration to design, construct, and evaluate an energy conservation demonstration office building in Manchester, New Hampshire. Comprehensive energy analysis calculations were followed by experimental validation by securing at least two years of continuous (hourly) data acquisition for building thermal performance and energy consumption. This project also covers the design procurement and evaluation of a solar heating and cooling system.

ENERGY CONSERVATION IN GARDEN APARTMENTS

Max Needleman
Building Environment Division - 301-921-3512

Sponsor - Federal Energy Administration

Heating and cooling loads are being measured for a garden apartment complex. These loads will then be compared with corresponding values after techniques to reduce energy consumption are installed. These retrofit measures include installation of storm windows, addition of solar shading devices to the window systems, and installation of a device to record the on-off cycle of the heating and air-conditioning system. The National Bureau of Standards Load Determination (NBSLD) computer program will be used for predicting pre-retrofit and post-retrofit heating loads for three instrumented apartments. Then, NBSLD will be used to predict heating loads for the whole apartment complex, permitting the reductions in heating requirements to be quantified. This procedure will be repeated during the summer season, permitting the reduction in cooling energy requirements to be quantified.

TWIN RIVERS ENERGY CONSERVATION

Heinz Trechsel
Office of Energy Conservation - 301-921-3892

Sponsor - Energy Research and Development Administration

This project is operating in concert with the National Science Foundation project, "Energy Husbandry in Housing," being conducted by Princeton University. The study is a two-year effort consisting of a planned retrofit experiment in townhouses at Twin Rivers, New Jersey, and the development of a series of manuals for specific audiences of the building community. Low-cost retrofit experiments are being conducted to provide quantitative data for retrofit manuals. An energy conservation guide for homebuyers and an operating manual for homeowners will be developed. During FY77, an experiment will be conducted to provide a measured data base for a retrofit manual that starts with the assumption that an investment in energy conservation will be made. Other manuals to be produced in FY77 include a manual for small builders, a manual for state and local officials, a manual for large builders, developers, architects and engineers, and a handbook for the building research community.

SUPPORT: COMMUNITY SERVICES ADMINISTRATION WINTERIZATION PROGRAM

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

Sponsor - Community Services Administration

Since it has become imperative to conserve energy and energy costs are increasing, the Community Services Administration (CSA) has established a program to winterize the homes of those least able to afford retrofitting to conserve energy—the poor. The Center will assist the CSA in its program by developing performance criteria and retrofitting guidelines, and providing technical assistance in reviewing and evaluating methodologies. This includes the development of a comprchensive plan plus immediate technical assistance for the CSA.

After analysis of the state-of-the-art in retrofitting for energy conservation of low-income family housing, including past and ongoing CSA projects, a comprehensive plan of research and technical assistance will be developed. Included will be: investigations into the performance of existing materials and methods; evaluations of the CSA pilot project in Colorado; technical and economic evaluations of innovative retrofit options; development of criteria for use in guidelines in addition to assisting in the development of the guidelines themselves. The work will be carried out by an interdisciplinary team of architects, thermal engineers, building economists, material specialists, and others.

COMPUTER CONTROL OF HEATING, VENTILATING AND AIR CONDITIONING EQUIPMENT FOR ENERGY CONSERVATION

David Didion
Building Environment Division - 301-921-2994

Sponsors - National Bureau of Standards
Federal Energy Administration

To determine the operational control techniques that will provide the greatest, and most practical, savings in the general purpose laboratories at the National Bureau of Standards (NBS), an experimental program is being conducted. It entails the automation of mechanical systems, central computerized control, and metering of selected zones in an NBS building under a variety of control patterns and seasons. Based on these results and practical operating experience, a more realistic determination can be made of the methods to be used in the remaining general purpose labs and in the NBS Administration Building. The experimental data verifying the computer simulation model will allow for generalization to other office buildings of similar systems.

The Center will install instrumentation and controls in the ten air handlers in the building. Signals from these points will be sent to a central computerized control panel, which will determine the mode, or modes, of operation that will result in the most efficient operation compatible with the laboratory requirements. Measurements of the energy consumption will be made during four seasons to determine the energy savings achievable through the automation of the heating, ventilating and air conditioning systems serving the general purpose laboratories at NBS.

VENTILATION SYSTEMS FOR ENERGY CONSERVATION

Tamami Kusuda
Building Environment Division - 301-921-3501

Sponsor - National Bureau of Standards

Since approximately 30 percent of energy used for heating and cooling a building is spent for processing ventilation air, it is important to design and operate ventilation systems efficiently.

The approach is to study the amount of outdoor air needed for the well-being of the occupants and to develop methods of controlling ventilation rate according to the needs of the occupants. In conjunction with an Energy Research and Development Administration-supported project, actual buildings will be operated under planned ventilation modes, and the occupants' responses will be studied simultaneously. The specific approach taken in this project is to study the build-up of various room air contaminants under various modes of ventilation control, types and location of ventilation air sensors, and the variable volume systems and a reheat system. This study will use the National Bureau of Standards computer program that simulates the performance of air-side (ventilation) systems.

EQUIPMENT MAINTENANCE FOR ENERGY CONSERVATION

Joel Levy
Technical Evaluation and Application Division - 301-921-3701

Sponsor - Federal Energy Administration

Better maintained equipment will use less energy per unit of output. Under these conditions, it becomes profitable to increase the level of equipment maintenance used to deliver building services. The purpose of this study is to develop a model that will permit quantification of the appropriate level of maintenance in terms of performance attainment and relative costs. Such a model will help decision-makers select economically efficient levels of maintenance for elements of building services equipment such as heating, ventilating, and air-conditioning systems, illumination equipment, and elevators and escalators.

A finite-state, finite-action-space Markovian dynamic programming model of equipment performance as a function of maintenance levels will be constructed. An algorithm for finding the best maintenance policy will be written in the BASIC computer language. The model will be applied in an illustrative example.

FIELD STUDY OF OIL BURNERS

George Kelly
Building Environment Division - 301-921-3521

Sponsor - Federal Energy Administration

Improving the seasonal performance of residential oil burners can save considerable energy. This program is aimed at determining how this can be done and evaluating the potential energy savings that could result from various modifications.

A procedure for reducing nozzle size and for recognizing oversize units will be developed. Then, a field study will be made to evaluate further reductions in the firing rate achievable through burner modification and changes in the fire box.

During FY75, data were obtained on the effect of annual

oil burner tune-up and the potential energy savings resulting from the reduction of nozzle size on oversized installations. The projected average seasonal fuel and cost savings obtained by a 29-percent reduction of the average nozzle size of a representative mix of oil-burner systems in New England were 5.2 percent and 3.7 percent, respectively. Savings for four other system mixes, representative of other U.S. regions, were also derived.

The analysis indicates that the control of excess combustion air is an essential factor in the amount of energy savings realized. The study found that (1) up to an 8-percent fuel saving could be achieved by nozzle size reduction if the percent of excess air could be maintained constant; and (2) the savings would be increased to 15.7 percent if the nozzle size reduction could have been coupled to a reduction in excess air from the "as found" average of 85.7 percent to 40 percent (equivalent to a 21.5 percent reduction of combustion air).

Energy Conservation in Communities

MODULAR INTEGRATED UTILITY SYSTEMS: DEMONSTRATION

Clinton Phillips
Office of Energy Conservation - 301-921-3741

Sponsor - Department of Housing and Urban Development

The Modular Integrated Utility Systems (MIUS) demonstration is the first fully integrated plant demonstration providing electrical, thermal, solid waste management, and wastewater management community services. The Center's successful involvement in the MIUS Total Energy Demonstration for the Department of Housing and Urban Development (HUD) has resulted in the Center being given lead technical responsibility. The Center for Building Technology will develop and implement the MIUS design monitoring and evaluation plan of the plant similar to that provided in the Total Energy Demonstration. The design monitoring requires that the National Bureau of Standards (NBS) be responsible for evaluating the design of the MIUS plant in accordance with the NBS-prepared performance specification.

In FY75, the Center provided energy, economic, and environmental analyses of proposals received in response to HUD's MIUS Demonstration request for proposals. Initial program plans for the complete demonstration design monitoring and performance evaluation were developed.

MODULAR INTEGRATED UTILITY SYSTEMS: DESIGN, ANALYSIS AND TECHNICAL SUPPORT

John Ryan
Office of Energy Conservation - 301-921-3741

Sponsor - Department of Housing and Urban Development

Although the principal technical study resources of the Department of Housing and Urban Development (HUD)-Modular Integrated Utility Systems (MIUS) program are in other participating agencies, the Centers' expertise is used to knit together the technical output, to assist HUD in the technical direction of the program, and to review other participating agency documentation for publication.

Four efforts have been identified under the Design, Analysis and Technical Support Program: Performance Specifications; Economic and Institutional Studies; Technical Reviews; and Technology Evaluations.

In the performance specification effort the Center is developing a document which contains the minimum performance quality levels of the MIUS products and services: reliability, energy efficiency, control, environmental impact, natural hazards resistance, occupational safety, and community impact.

Under the Economic and Institutional Studies effort, the Center is conducting cost/benefit, economic feasibility, and marketing studies, to develop methodologies for such analyses and to identify and develop solutions to institutional, legal, and governmental factors which constrain, delay or prevent the implementation of the MIUS concept.

In the Technical Review effort the Center for Building Technology is conducting coordinated technical reviews of certain MIUS program documentation and performing less rigorous reviews of other program documentation.

In the Technology Evaluation effort the Center is

conducting investigations in several key areas of MIUS technology. Particular emphasis is placed on those technologies where particular NBS expertise exists. For example, technology evaluation of heat pumps relative to MIUS technology and of the integration of wastewater treatment in MIUS is being performed. A new task concerned with the field-based laboratory investigation of solid waste incineration/heat recovery/MIUS integration of the Jersey City Total Engery Demonstration site was initiated. In addition, completion of earlier efforts is anticipated in FY76: publication of the MIUS technology evaluation of computer software; the solid waste data base; and an electrical load profile.

MODULAR INTEGRATED UTILITY SYSTEMS: PROJECT MANAGEMENT

Clinton Phillips
Office of Energy Conservation - 301-921-3741

Sponsor - Department of Housing and Urban Development

The Department of Housing and Urban Development (HUD)-Modular Integrated Utility Systems (MIUS) program is studying—by means of real-life demonstrations—the improvements to be obtained by integration in furnishing the essential utility services for communities. The utilities of principal concern are electric energy, heating and cooling, liquid and solid waste management and potable water. Integration of the facilities for providing these services minimizes net environmental impact and permits optimization of energy utilization, mass flow, resource demand, management/maintenance labor, and plant sizing. The project consists of several principal subelements: Technical Support, Total Energy Demonstration and MIUS Demonstration.

MODULAR INTEGRATED UTILITY SYSTEMS: PROGRAMMATIC SUPPORT

Clinton Phillips
Office of Energy Conservation - 301-921-3741

Sponsor - Department of Housing and Urban Development

The Center, under the Department of Housing and Urban Development (HUD) Memorandum of Understanding on the Modular Integrated Utility System (MIUS), has provided programmatic management support to HUD for the overall multi-agency HUD-MIUS program. For the past year the Center has monitored the overall direction of the program, made technical and managerial recommendations to HUD, participated in interagency discussions as support to HUD, represented HUD in various roles, and provided a management information system service to HUD.

During FY75, information systems were developed, accepted by HUD, refined, and maintained. Final duplication and organization of the MIUS technical reference file was completed. The Center developed and maintained a program control and monitoring information system in a MIUS situation room display at the National Bureau of Standards.

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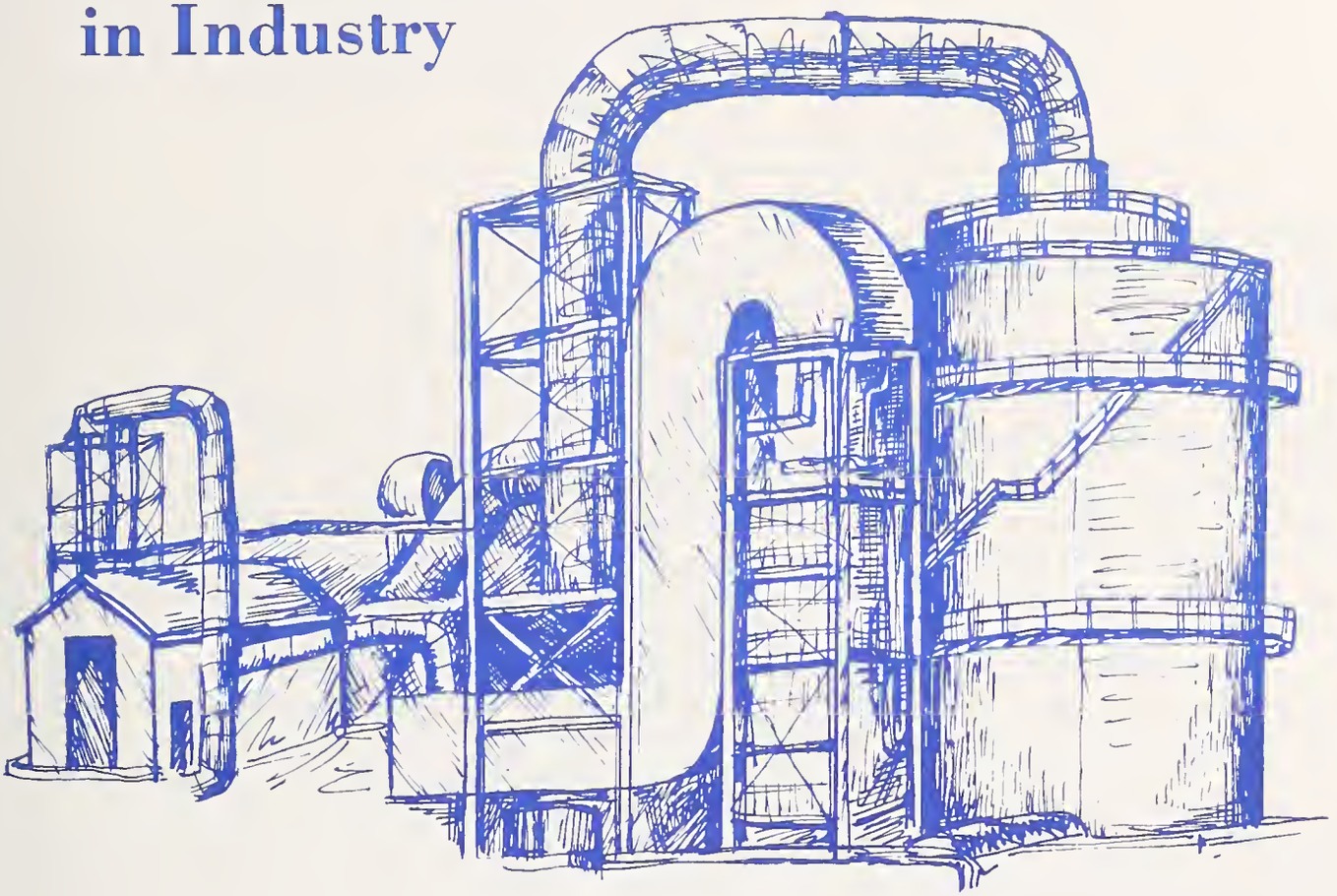
ENERGY CONSERVATION HANDBOOK

Clinton Phillips
Office of Energy Conservation - 301-921-3741

Sponsor - United States Air Force

This research will identify and consolidate energy conservation measures, determine their applications to Air Force facilities, and prepare an energy conservation handbook for use by the Air Force base engineers. The handbook will explain energy conservation options and procedures for retrofit of existing facilities. In addition, the handbook will present benefit/cost analysis procedures for computation of potential savings and amortization data for alternative energy conservation measures. Health, safety, and environmental impact will also be considered. Special portions of the handbook will be devoted to conducting building surveys and energy audits.

Energy Conservation in Industry



INDUSTRIAL ENERGY MANAGEMENT PROGRAM

Kenneth Kreider
Office of Energy Conservation - 301-921-3275

Sponsor - Department of Commerce

The Department of Commerce (DoC) has developed a program, based on the National Bureau of Standards (NBS) Handbook 115, *Energy Conservation Program Guide for Industry and Commerce* to assist industry and commerce in adjusting to the increased cost and shortage of energy. The Center is supplying the scientific and technical support to DoC.

Specific projects in the Center's effort include supplements to Handbook 115, a guidebook specifically for small businesses engaged in light industry and commerce, a college course guide for energy conservation practices, case studies in small businesses, a waste heat engineering guidebook, and process energy conservation manuals for such areas as steam systems, furnaces, kilns, and ovens. The Center will also provide, as requested, technical review and analysis of industrial processes, research proposals, and legislative proposals in energy conservation; technical support for workshops; and program management for effective coordination of NBS projects and for interactions with other government, academic, and industrial institutions.

TECHNICAL ASSISTANCE AND ANALYSIS FOR INDUSTRY

Kenneth Kreider
Office of Energy Conservation - 301-921-3275

Sponsor - National Bureau of Standards

Lack of a firm technical base in energy conservation will seriously hamper national efforts in energy conservation and selection and implementation of Federal fiscal and regulatory initiative, since the problem of excessive energy consumption is based on effective technology.

To aid industry in voluntary energy conservation projects, the following activities are being undertaken:

- An assessment of the use of the National Bureau of Standards (NBS) Handbook 115, *Energy Conservation Program Guide for Industry and Commerce (EPIC)* in five industrial plants has been commissioned with the University of Tennessee.
- A Catholic University study is being used to help develop the EPIC program for light industry and commerce.
- A university engineering course on energy management, based upon EPIC, is being developed.

An assessment of the role of measurement technology and controls in energy conservation in industry is being carried out. A system will be developed for evaluating energy fluxes in an industrial process, and recommendations will be made on ways to monitor and control these fluxes. In addition, an effort will be made to gain insight into possible technical developments aimed at improved energy control.

The NBS role in combustion technology is being assessed. In particular, NBS is examining the measurement research needs of the industrial community and the

appropriate roles of NBS, the national laboratories, and private organizations.

The use of improved thermography for industrial plant surveys is being further developed and applied to process heat balances and plant energy audits. Quantitative studies will be carried out on selected industrial facilities, including before and after studies on the effects of energy conservation measures on patterns of radiant energy losses.

ESTABLISHMENT OF A DATA BASE FOR COMBUSTION MODELING

Kenneth Kreider
Office of Energy Conservation - 301-921-3275

Sponsor - Energy Research and Development Administration

In recent years a major advance has taken place in the quantitative computer modeling of large scale chemical and engineering systems. The usefulness of present-day computer models is strongly dependent on a detailed and accurate description of the elementary chemical reactions and thermal properties of the reactive intermediate radical and ionic species. The mathematical models have now become crucial tools in combustion systems development and control. In particular, they are invaluable for the proper interpretation of bench and pilot plant experiments. At the elementary chemical reaction level, the data are pertinent to many different system models, and there is an overriding need for consistency, as well as accuracy, in the data base used when different organizations attack the same problem area. This creates a need not only for measurements, but also for development of new and more accurate measurement techniques and computerized data activities.

The National Bureau of Standards (NBS) will address the development of accurate data on the mechanisms, rates and energetics of selected classes of combustion reactions. These data are used not only in combustion, but also in many other sectors of technology to develop quantitative models of diverse high temperature systems to aid in the description and control of flames, plasmas, combustion systems and petrochemical processes. The project activities include development and definition of measurement techniques, accurate measurements and compilation, evaluation and dissemination of data.

NBS is assessing where the data needs for combustion research and combustor development are most urgent, and engaging in data measurement, compilation, and analysis, aimed at producing a series of reports presenting reliable and consistent data on those reactions for which such data are most urgently needed.

ENERGY CONSERVATION IN BLENDED CEMENT

At present, portland cement manufacture requires almost one percent of the energy consumed in the U.S. The replacement of a portion of this material by a suitable waste product such as fly ash will result in a substantial

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Sponsor - Energy Research and Development Administration

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 U.S., their value has been demonstrated by extensive use in other industrialized countries.

In this project, the reactions of blended cements containing waste and by-product materials will be studied to provide insight to the important variables in the choice of cement replacement materials. The effect of the replacement materials on the alkali-aggrcgate reaction, sulfate resistance, strength development, and durability of blended cements will be evaluated to provide a basis for performance tests and criteria.

The study of the alkali-aggregate and sulfate attack reactions will be carried out by chemical analysis, X-ray diffraction, scanning electron and optical microscopy, thermal analysis, and mechanical property measurements. Although tests will be carried out in accordance with the American Society for Testing and Materials (ASTM) procedures, new tests will be developed where needed. The new tests will be submitted for consideration by ASTM.

CHARACTERIZATION OF WASTE PAPER PULPS

Kenneth Kreider
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Sponsor - Energy Research and Development Administration

Paper recycling results in considerable savings in energy consumption per ton of paper produced; no logging or pulping is required in paper recycling. However, most waste paper is composed of a mixture of paper grades. There is a limited use for this waste paper, regardless of the quality of the paper in the mixture, since the paper industry is not accustomed to working with unknown fiber mixtures. If pulp made from mixed waste paper were characterized and graded, there would be greater incentive to recycle, since this waste could be used to make more than just the lowest of paper grades.

In this project, test methods are being developed to supply the data necessary to characterize and grade pulps made from mixtures of assorted fibers. At first, mixtures will be made from identified and characterized pulps according to a statistical sampling plan. Fiber-length distribution will be determined by an image-analysis technique, and the specific surface of the pulps in aqueous suspension will be determined. Paper will be made on a laboratory scale, and the physical properties of the paper will be determined. Fiber strength and bondability will be determined by a short-span tensile technique. A complete statistical analysis of the data will determine the best means for predicting paper properties from pulp properties. Finally, pulps will be made from mixed waste paper,characterized, graded, made into paper, and evaluated to compare predicted with actual properties.

Increased recycling would result in lower energy consumption by the paper industry, and many solid waste problems for municipalities would be alleviated.

Energy Savings through Performance Codes and Standards

PROGRAM MANAGEMENT FOR STANDARDS RESEARCH AND DEVELOPMENT

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Sponsor - Energy Research and Development Administration

The objective of this project is to provide the program management services to obtain the conceptual models and research data needed as a basis for drafting energy conservation standards of the performance type.

The Office of Energy Conservation, Center for Building Technology, will act as technical program manager for planning and integrating the Energy Research and Development Administration (ERDA)/the National Bureau of Standards (NBS) research projects for development of the energy conservation performance standards (as defined in the Modification of ERDA/NBS Memorandum of Understanding, November 1975), planning and integrating the relationships of similar work funded by all other agencies at the NBS, and coordinating with and integrating the products of directly related work funded by the ERDA at other locations and work performed by private organizations.

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS AND NATIONAL FIRE PROTECTION ASSOCIATION STANDARDS FOR ENERGY CONSERVATION

Paul Achenbach
Building Environment Division - 301-921-3637

Sponsor - National Bureau of Standards

ASHRAE Standard 90-75, *Energy Conservation in New Building Design* was issued by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), in collaboration with the Illuminating Engineering Society (IES), in October 1975. It is the nation's first comprehensive energy conservation standard that is applicable to all types of new buildings.

ASHRAE 90-75 is based on a research document, NBSIR 74-452 *Design and Evaluation Criteria for Energy Conservation in New Buildings*, published by the National Bureau of Standards in February 1974 in response to a request from the National Conference of States on Building Codes and Standards (NCSBCS), an organization of building regulatory officials from State and local governments.

Current ASHRAE energy conservation activities involve the development of a proposed ASHRAE Standard 100 series for retrofitting existing buildings for energy conservation and continuing update of ASHRAE Standard 90-75. During FY76, a Center for Building Technology staffer will serve on the technical panels, drafting the 100 series and updating 90-75.

BUILDING ENERGY CONSERVATION STANDARDS

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Sponsor - Department of Housing and Urban Development

Approximately one third of the energy consumed in the U.S. is used by the building sector. It has been estimated that 40 to 50 percent of energy used in new buildings could be saved by energy conserving designs. Building performance standards (e.g., energy budgets) represent a logical extention of the performance concept now developed at the level of a component performance standard, such as in the American Society of Heating,

Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90-75. Building performance standards—standards that limit the annual energy usage of buildings—focus on energy conservation as a performance concept, provide energy design objectives, and demand an approach to design without direct constraints on design options.

The purpose of this Department of Housing and Urban Development (HUD) sponsored project is to develop objectives, a technical approach and a detailed program plan for formulating and implementing energy conservation performance standards for new buildings. The motivation for the standards implementation program is to assure effective application of the standards for energy conservation. To the extent that standards are performance-oriented, they increase the complexity of evaluations for design approval by building regulatory agencies, in comparison with prescriptive standards that specify the materials and methods to be used.

The technical program for standards development and standards implementation will be managed by the Center for Building Technology for the Secretary of HUD, in response to policy direction from the Energy Resources Council Task Force on Thermal Standards. In the preliminary plan the management framework of coordinating various other agency roles, the Federal Energy Administration has policy overview; HUD, implementation; the Energy Research and Development Administration (ERDA)/NBS, research, development and demonstration; and the General Services Administration, implementation. Initial ERDA/NBS research projects related to the standards program are described elsewhere in this document.

MODEL DOCUMENTATION FOR ENERGY STANDARDS

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

Sponsor - Energy Research and Development Administration

This project involves the development of model informational documentation and procedures to facilitate the adoption and implementation of building energy conservation standards of the component performance type. State-of-the-art studies of existing regulatory programs and systems dealing with building energy conservation will be conducted and documented to provide a basis for a coordinated national system to be available when standards are promulgated. The approach will be patterned after the existing National Bureau of Standards Coordinated Evaluation Systems project for manufactured buildings.

ECONOMICS IN BUILDING STANDARDS

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

Sponsor - Energy Research and Development Administration

Economic analysis to support the National Bureau of Standards building energy conservation standards program is being conducted during FY76. This project is primarily empirical in nature, applying economic methodologies developed in support of the standards program. The extent to which appropriate energy conservation techniques might be economically justified for buildings of different types, in different climates, and using different energy forms will be objectively determined using life-cycle cost and energy savings data. Recommendations for performance standards will be made based on this analysis.

Economic optimization models based on marginal analysis are being applied to the energy conservation design of residential, commercial, and public buildings. Cost data relevant to energy conservation in new buildings are being collected by a contractor for use in running the model. A computer program will be used in estimating annual savings for various combinations of energy conservation features in buildings of different types and in different climates. Economically optimal combinations of energy conservation techniques sensitive to climates, economic factors, and user requirements will be estimated. Commercially available computer programs will be used where necessary to supplement the National Bureau of Standards Load Determination computer program.

ENERGY BUDGET APPROACH FOR BUILDING STANDARDS

William Carroll
Building Environment Division - 301-921-3503

Sponsor - Energy Research and Development Administration

The technical aspects of an energy budget concept as the basis of energy performance standards in buildings will be explored and developed. In addition to the concept definition, methods of application, including building and climate classification schemes and simple and reliable calculation methods, will be developed by a multidisciplinary approach using related economic, architectural and human factors experts. This methodology will subsequently be employed in a separate project to produce energy budgets for all classified building types, functions, and climatic conditions. Energy budgets will provide a reliable, effective evaluation tool to aid in the development of building energy performance standards, which will stimulate energy conservation practice in building design, while allowing the freedom for innovation.

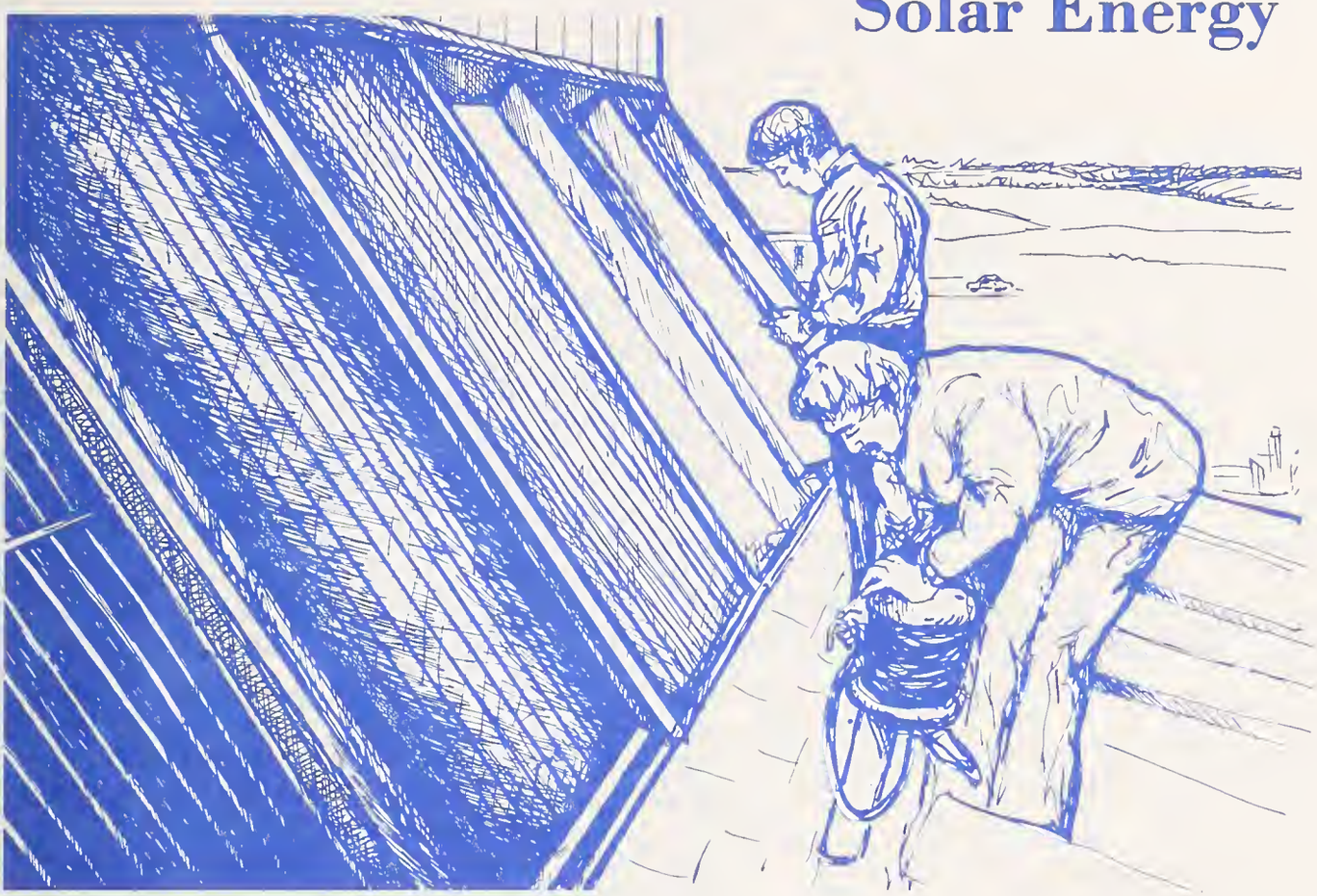
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION TECHNICAL AND PROFESSIONAL SERVICES

Jim Heldenbrand
Office of Energy Conservation - 301-921-3892

Sponsor - Energy Research and Development Administration

Technical and professional services will be provided by the National Bureau of Standards (NBS) staff to support the Energy Research and Development Administration (ERDA) in its overall research and demonstration responsibility for the Energy Performance Standards Program. This support to ERDA supplements the NBS responsibility for overall technical program management in response to policy direction from ERDA, the Federal Energy Administration and the Department of Housing and Urban Development.

Solar Energy



SOLAR ENERGY PROGRAM FOR HOUSING SYSTEMS

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Sponsor - Department of Housing and Urban Development

In view of the current energy crisis and the increasing rise in the cost of fossil fuels, the Department of Housing and Urban Development (HUD) initiated a cooperative program with the National Bureau of Standards (NBS) to determine the feasibility, use, and performance characteristics of solar energy systems and dwellings using such systems.

To develop interim performance criteria, an interdisciplinary team of the Center for Building Technology staff members was organized. This team prepared criteria drafts that were reviewed by a 10-member consultant evaluation panel consisting of experts from the solar energy field. In addition, drafts were reviewed by Federal agencies responsible for the residential demonstration program, HUD and the National Aeronautics and Space Administration. General public and industry comments were also solicited and obtained through an open conference held at NBS in November 1974.

The *Interim Performance Criteria for Solar Heating and Combined Heating/Cooling Systems and Dwellings* was completed on schedule and transmitted to HUD. Minor modifications were made to this document and it was published for general distribution in February 1975.

NBS is developing a plan for HUD which will describe the technical performance data to be collected during the solar residential demonstration program. NBS will also prepare *Intermediate Minimum Property Standards for Solar Heating and Domestic Hot Water Systems.* These standards will be a supplement to HUD's Minimum Property Standards for single family and multifamily housing.

SOLAR ENERGY DEMONSTRATION PROGRAM

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Sponsor - Department of Housing and Urban Development
Energy Research and Development Administration

An interdisciplinary team of the Center for Building Technology staff members is organized to develop the interim performance criteria for the solar energy commerical demonstration program. Public and industry comments on these criteria will be solicited before final publication. The team will monitor the design, construction, and operation of commercial solar energy systems and feed back the information thus obtained in the development of the final performance criteria. The testing and evaluation of systems and subsystems developed under the research and development phases of the heating and cooling program will be monitored and reviewed, as well as those recommended for demonstration, testing, and further development under the commercial demonstration program. In addition, consultant and advisory service will be provided to the Energy Research and Development Administration for the review of various grants and proposed programs of study.

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

James Hill
Building Environment Division - 301-921-3512

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 system for 18 months. Measured data will be compared with predicted data for several operational 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 in 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 the performance predicted with available analytical models. Emphasis will be placed on evaluating the performance of the system in a variety of modes of operation.

SOLAR ENERGY STANDARDS

James Hill
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Sponsor - National Bureau of Standards

The National Bureau of Standards (NBS) staff are participating in committees to develop standards for solar energy collectors, storage devices, and systems. The development of these standards is in response to a national need to conserve fossil fuels and to use renewable fuel sources such as solar energy. NBS is in a unique position of having the laboratory facilities and technical expertise to make a significant contribution. During FY76, the Center will complete draft standards on solar energy collectors, storage devices, and systems. The Center will also participate with the American Society for Testing and Materials, the American Society of Heating, Refrigerating and Air-Conditioning Engineers, and the American National Standards Institute, Inc. committees to assist in the preparation of national conservation standards.

Economics

TECHNIQUES FOR ECONOMIC EVALUATION OF BUILDINGS

Harold Marshall
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Sponsor - National Bureau of Standards

The objective of this project is to develop and refine the theories and methods of benefit-cost analysis, risk-benefit analysis, and life-cycle costing for applications to building evaluations.

The approach is as follows: (1) to conduct a literature search on available evaluating methods and statistical data, both in the U.S. and abroad; (2) to examine non-building applications of evaluation techniques to determine their applicability to building problems; (3) to examine alternative methods for evaluating losses of life and personal injuries; (4) to examine techniques for evaluating alternative building designs for preventing losses from fire and other disasters, and for reducing the consumption of energy; (5) to examine cost-sharing rules as they impact on construction design and scale; (6) to increase the Center for Building Technology awareness of the applicability of economics to building problems and include economics in interdisciplinary research through seminars and workshops.

Last year, benefit-cost, risk-benefit, and life-cycle cost methods were refined for evaluating alternative building technologies. The staff participated in seminars, training, and research relating to applications of these methods. Specific accomplishments included a Federal workshop on building economics, publication of four papers in the proceedings of the Purdue University Conference on *Heating, Ventilating, and Air-Conditioning Equipment and Components for Buildings*, preparation of three articles for submission to professional journals, completion of a chapter in *Salinity in Water Resources*, and completion of a report, *Solar Heating and Cooling of Buildings: Methods of Economic Evaluation.*

ECONOMIC ANALYSIS OF BUILDING CODES

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Sponsor - National Bureau of Standards

In recent years construction costs have risen faster than the general cost of living, and many persons contend that the construction industry is technologically backward and inefficient. Some observers believe that restrictive building codes promote inefficiency and substantially increase cost, while other experts believe the impact of building codes exists in part due to the lack of appropriate information. This study will develop an economic framework to help identify the impact of building codes on construction costs, and upon the distribution of income between buyers, builders, building material producers, and construction workers.

To increase information, an *Economic Impact Statement* will be developed that will provide a standardized method of analyzing the economic impact of a specific building code change. Building officials seek to improve public health, safety, and welfare through building codes.

The economic impact statement will be designed to be especially useful to building officials in choosing between two code alternatives, or between the choice of enacting or not enacting a code change. The study will conclude with a case study of one particular code change to illustrate the use of the economic impact statement.

ECONOMIC ANALYSIS OF LEAD-PAINT ABATEMENT TECHNIQUES

Robert Chapman
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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 the optimal abatement technique is neither readily apparent nor easily determined. This study will assist the urban planner to make the choice among abatement techniques for a given set of constraints (e.g., surface type, substrate condition, occupancy status) by providing (1) an analysis of the determinants and structure of costs at the abatement technique level and (2) an analysis of performance characteristics of the alternative techniques.

ECONOMICS OF ENERGY CONSERVATION

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

Sponsor - National Bureau of Standards

Twelve percent of the national energy supply is consumed in residential space heating and cooling operations. Yet much of this energy is wasted due to inadequate thermal insulation. If homeowners can determine how energy conservation retrofitting techniques will benefit them in economic terms, they may respond faster and more accurately to national energy conservation requirements.

Last year, most of the information and methodologies for the homeowners report were generated in preparing a technical study on optimal combinations of energy conservation retrofitting techniques for residential application. The approach this year was to assemble this information to be easily interpreted by the layman interested in reducing the energy requirement of his home. The booklet entitled *Making the Most of Your Energy Dollars in Home Heating and Cooling* includes allowances for climatic conditions, current fuel prices, the rate at which fuel prices are rising, and the cost of specific retrofitting techniques.

ECONOMIC EVALUATION OF ROOF AND WALL SECTIONS

Phillip Chen
Technical Evaluation and Application Division - 301-921-3701

Sponsor - Tri-Service Committee

For military construction of administrative housing, recreation and hospital facilities, the Center is compiling technical, construction, and energy cost information for a 25-year life cycle on wall and roof sections generally used or potentially suitable in the Washington, D.C. area. This information, intended for use by the building designer, will highlight energy conservation and labor-saving materials.

ECONOMIC MICROSTUDIES OF NEW BUILDING PRACTICES

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

Sponsor - National Bureau of Standards

This project developed a benefit-cost methodology for measuring the net social impacts of improvements in technology that are introduced through the building regulatory system and through the building industry on a voluntary basis. Impacts studied are social benefits and costs that result from the introduction of reduced-sized venting in plumbing and improved standards and practices in roofing.

ECONOMICS OF SITING BUILDINGS

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

Sponsor - National Bureau of Standards

The economics of location and the determinants of site advantage, previously developed as part of this project, will be extended. The Center will devise quantitative measures of the characteristics of location that describe the relative site advantages of residential locations. These variables will then be used in an econometric model to estimate their relative importance on the structure and level of the submarket demand for housing. The data used to estimate this model will be based on special cross tabulations from the 1970 *Census of Metropolitan Housing*. Two reports, *The Economics of Siting Buildings* and *The Impact of Residential Site Selection on Housing Demand* will result from this research.

FENESTRATION: ECONOMICS

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

Sponsor - National Bureau of Standards

The capital and maintenance costs of alternative window characteristics, as well as psychological benefits and costs, are important to the overall efficiency of window selection. An 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. Any preliminary measures of psychological benefits and costs identified by the Center's Sensory Environment Section from the existing literature will be related to the life-cycle cost measures.

EFFECTS OF "RESOURCE IMPACT FACTORS"

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

Sponsor - Federal Energy Administration

This project will assess the efficiency and energy conservation impacts of alternative "Resource Impact Factors" (RIF's). Criteria for specifying RIF's that will provide the price or cost information necessary for generating efficient energy conservation standards for buildings are also being developed. These RIF's are necessary for the development and application of an economically efficient energy conservation performance standard for buildings.

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The study will compare the performance requirements of energy conservation standards generated with and without RIF's, and will examine the impact on the proposed performance standard that might result from various RIF values. Consideration will also be given to the extent to which RIF's should be specified nationally or regionally.

A report has been completed, *Evaluation of Energy Resources in the Development of Performance Standards for Energy Conservation in Buildings*, which addresses economic formulation of energy performance standards. This report lays the groundwork for introducing RIF's into the process of standards development by demonstrating the need for making the standard depend on the relative and absolute social values of energy resources.

HOUSING NEEDS IN DEVELOPING COUNTRIES

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

Sponsor - Agency for International Development

This project published the report *The Economics of Building Needs: A Methodological Guide*, prepared for meetings on "Development of Design Criteria and Methodology for Low-Rise/Low-Cost Buildings to Better Resist Extreme Winds" in Manila, the Philippines and Kingston, Jamaica. The work established a method by which housing needs can be forecasted. It thus established the relative economic importance of improved design criteria and construction methods.

Sensory Environment

NOISE IN AND AROUND BUILDINGS

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

Sponsor - National Bureau of Standards

Light weight materials, prefabricated systems, and emphasis on open-space planning has resulted in increased exposure of building occupants to indoor and outdoor noise. The higher noise levels have led to an increased awareness among governmental agencies, builders, architects, and the public of the need for a quieter environment. The National Bureau of Standards initiated a research program designed to assess and improve the design tools now available to architects and builders concerned with the acoustical environment of buildings.

The emphasis is on identifying the main factors associated with human response to noise in buildings and evaluating how well current methods account for those parameters.

Such studies consist of obtaining a "library" of household noises as they actually occur in dwellings through the use of tape recordings. They will be analyzed and assessed by human observers. The results of these studies will provide the data base on human response to the acoustical climate of buildings for the purpose of improving criteria for use in standards, codes, and regulations.

CRITERIA FOR BUILDING NOISE

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Sponsor - Environmental Protection Agency

The Center for Building Technology is working with the Environmental Protection Agency on a program to develop improved acoustical criteria for buildings. This program consists of a review and evaluation of available data on indoor noise levels in dwellings. An examination will be made of human response data employed to validate acoustical rating schemes commonly used by building designers, to determine their applicability to building codes.

Another phase is concerned with the development of an experimental plan. The plan consists of a social survey and noise measurement techniques to assess the statistical distribution of indoor noise, its relationship to outdoor noise, and the reaction of building dwellers to their acoustical climates.

FENESTRATION: DESIGN

Belinda Collins
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Sponsor - National Bureau of Standards

The impact of the window upon the overall energy consumption of a building is not fully understood. Inputs from four separate disciplines, thermal engineering, economics, architecture, and psychology, will be used to investigate the performance of the window. This research project is being developed to discover ways of conserving energy through cost-efficient window design, while meeting both architectural requirements and user needs.

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.

Progress to date has included modification of the *National Bureau of Standards Load Determination Computer Program* to be suitable for the exterior envelope analysis, development of average-day solar radiation for energy analysis, and experimental evaluation of window-glass coating; a window design-study report; development of a life-cycle cost model; data collection on venetian blind usage; and publication of a literature evaluation of psychological reaction to environments with and without windows.

ILLUMINATION CRITERIA FOR BUILDINGS

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Sponsor - Energy Research and Development Administration

This project is developing a new basis for recommending levels of illumination that are more conducive to energy conservation. The present recommendations state that increasing illumination levels increase visibility, whereas the new function recommends an optimum luminance level. Levels higher than the optimum can lead to decreased visibility, along with consuming higher amounts of energy.

VISUAL ENVIRONMENT

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Sponsor - National Bureau of Standards

How much light do we need to perform specific tasks? The visual performance data currently used to recommend levels of illumination are based on the simplest type of visual requirement, threshold detection (I barely see that spot of light). Researchers, designers, and engineers who don't subscribe to the present recommended practices, argue that the experimental conditions under which the current recommendations are based are not simulations of real-world conditions. The Center has undertaken studies to obtain a more valid determination of illumination requirements; that is, visual performance evaluated under stimulus conditions more nearly resembling situations encountered in everyday life, suprathreshold levels (I see the target under both conditions, but it is more distinct under illumination condition A than B). Studies conducted with gratings and letters under suprathreshold conditions indicate a significant difference between the functions. The threshold function states that ever-increasing light levels result in ever-increasing visibility. The suprathreshold function states there is a luminance level that is best for performance and that increasing or decreasing luminance beyond this optimum results in a poorer image.

Another part of this project studies veiling reflectance. Light sources are installed in luminaires that redirect the light from the lamp to the desired location. The design and placement of these luminaires affect energy consump-

tion by the effectiveness of the light rays for visual task performance. An efficient luminaire will reflect more of the lamp light, but more importantly will direct the lamp output to the desired location with the correct geometry, resulting in a minimum of veiling reflection.

COLOR APPEARANCE

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

Sponsor - National Bureau of Standards

This project uses visual theory, mathematical modeling, and psychophysical experimentation in a continuing development of color science, with the aim of applying color to safety, communication, visual comfort, and esthetic satisfaction. Current surface-color emphasis is on development and popularization of a single master set of colors for all safety-coding applications. Current illumination-color emphasis is on evaluating formulas that have been proposed for predicting the luminances of colored lights seen as equally bright. The ultimate goal is a revised photometry and possible application to energy saving in lighting.

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.

Similarly, it has long been known that the standard procedure (used in photometers) for calculating the total luminous output of a light leads to errors that are sometimes quite serious. Development of a more accurate formula, and instruments based on it, will not only advance photometric science, but will permit realistic comparisons by lighting engineers of the outputs of different types of light sources. This research could also permit energy savings by encouraging the replacement of lights now over-rated in visual effectiveness by fewer lights of greater true effectiveness.

BEHAVIORIAL RESEARCH DESIGN APPLICATIONS

Arthur Rubin
Technical Evaluation and Application Division - 301-921-2177

Sponsor - National Bureau of Standards

This acitivity will promote the use of behavioral methods and data in the design process. An early study (user requirements in the home, a data-collection methodology) was a review of primarily survey research applicable to "user" studies in buildings. This investigation also touched upon other research approaches that might be appropriate for occupant studies of buildings, and indicated that a wealth of information, compiled in many disciplinary areas, is available for researchers concerned with defining

user requirements in buildings.

The most recent study, now nearing completion, is designed to be an in-depth examination of methodologies from a variety of disciplines that might be employed in user studies - and an evaluation of them from the standpoint of an experimental psychologist. The study is directed particularly to designers and architectural students in the hope of providing an insight into the relationship of behavioral research methodology and design, thereby improving communications between these two disciplines.

VISUAL TECHNIQUES IN NON-DESTRUCTIVE TESTING

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Sponsor - National Bureau of Standards

The human observer is currently the weakest link in nondestructive testing (NDT) systems that include a "visual" component. Field observations and interviews with NDT experts will be conducted to detail the information needs by NDT and describe the working environment as it impacts on NDT visual tasks. This information will be used to recommend change in current NDT practices.

Field trips are being made to installations now conducting NDT in radiography, magnetic particles, and penetrant techniques. The visual parameters involved are being identified in detail and procedures, standards, and optimum physical conditions under which tests can be performed will be recommended. They will be presented as *Considerations and Standards for Visual Inspection Techniques* at the National Bureau of Standards, the America Society for Testing and Materials, the American Society for Nondestructive Testing Symposium on Nondestructive Testing Standards.

Architectural Research

ARCHITECTURAL RESEARCH

Stephen Margulis
Technical Evaluation and Application Division - 301-921-3595

Sponsors - National Bureau of Standards; Department of Housing and Urban Development

National priorities have been set for safer buildings, for buildings that pollute less, and for buildings that conserve energy. But safety, pollution control, and energy conservation increase costs. These increases have, in turn, caused building costs to escalate. One answer to this is improved construction productivity. Whether factory-built residences could satisfy the Nation's need for housing was addressed in the Department of Housing and Urban Development's Operation Breakthrough, a large experiment to stimulate industrialization and innovation in housing. The Center is surveying and reporting the opinions, attitudes, and behavioral reports of those directly affected by this housing—its occupants. Their experiences with regard to safety, security, comfort, convenience, and other matters will be compared with those of occupants of conventional housing. This information, including conclusions and recommendations for the design and management of future housing, will be directed to the housing industry and the general public. In addition, a report on consumer information will be published.

Benefit-cost analysis assesses the goodness of design, for conventional as well as industrialized housing and for other building types as well. This research project is investigating the "benefit" aspects of benefit-cost analyses for buildings.

Building researchers and practicing professionals need to improve their communication skills, especially writing; likewise, new computer techniques are needed to increase productivity in building design and construction. Reports on both of these topics will be published. Fundamental to the application of research findings is the building performance approach, which has been adopted and furthered at the National Bureau of Standards. A report to establish a *Performance Theory for Architectural Design* will be prepared.

ARCHITECTURAL PSYCHOLOGY

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

Sponsor - National Bureau of Standards

Architectural psychology examines how people use the buildings designed and constructed for them, as a way of improving the design of future buildings. For example, in FY74 and FY75, privacy studies were begun to establish psychological knowledge in a subject area of great interest to the public, but one which previously had not been systematically researched. Behavioral studies in privacy are continuing, and will be augmented by studies in stair safety and building use by the elderly. Stair safety studies will complete research commenced in FY74 and continued in FY75 to set safety performance criteria aimed at reducing the number (350,000) of stair accidents each year. A monograph on human perception as related to building safety will be published. Studies will develop a research

method and findings on the use of nursing homes by old persons. A literature search on law enforcement facilities will be published, as will a report on the psychological aspects of architectural design. All architectural psychology research will result ultimately in research reports, performance criteria, standards, design guides, or user guidelines to improve the built environment for the benefit of the people who use and enjoy it.

FENESTRATION: ARCHITECTURAL

Robert Hastings
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Sponsor - National Bureau of Standards

Until recently, the energy consumption implications of architectural design decisions were of much concern. The mechanical and illumination systems could always be designed to compensate accordingly. Over-design and large safety factors made calculating design subtleties a superfluous endeavor. 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 result in a net reduction of these loads. This project will identify energy conserving design strategies for windows and evaluate the sensitivity of modeling methodologies and strategies. Among other considerations, this project will assist in the synthesis of architectural design strategies with the thermal, psychological, and economic constraints. An interdisciplinary methodology publication will then be published.

ARCHITECT-IN-RESIDENCE

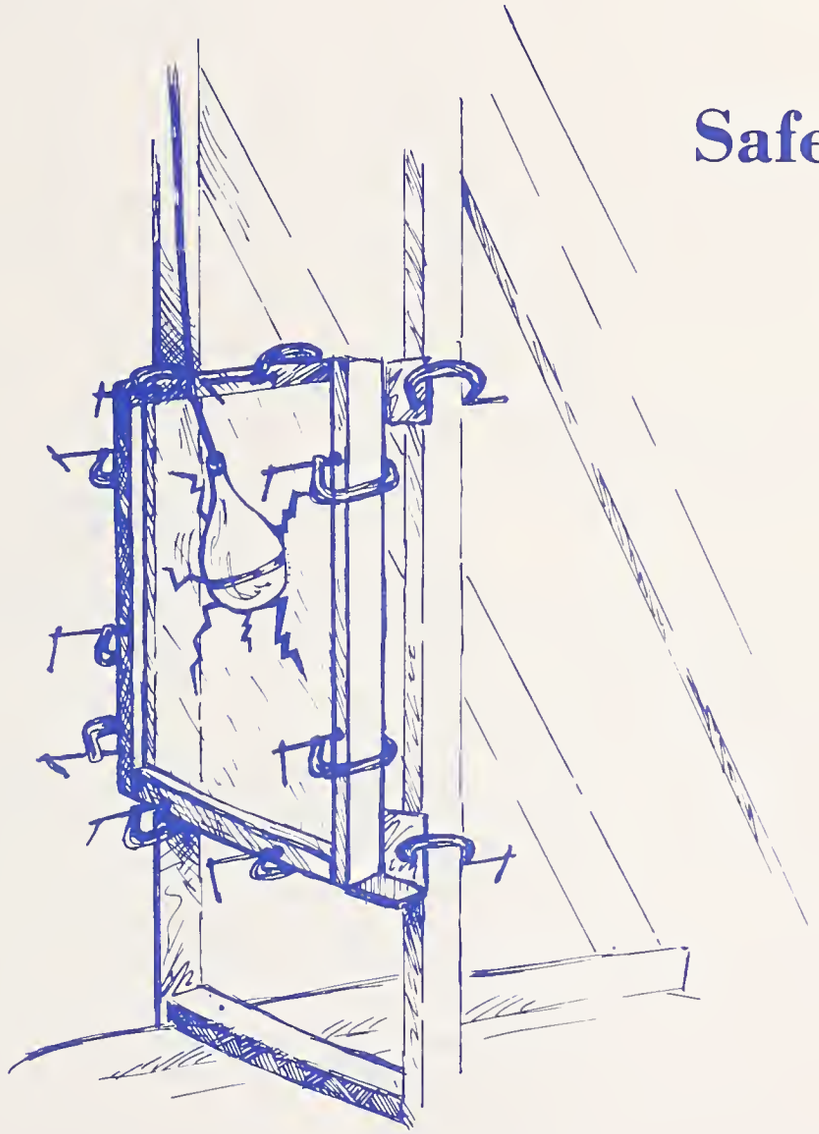
Porter Driscoll
Technical Evaluation and Application Division - 301-921-3704

Sponsor - National Bureau of Standards

To strengthen the link between the design professions and the building research community, a new post has been developed at the National Bureau of Standards (NBS). The American Institute of Architects (AIA)/NBS Architect-in-Residence Edward C. Fordyce, Assistant Director of Planning, Science Museum of Virginia was recently selected by the two organizations and will remain in residence at the Gaithersburg campus for a period of approximately one year. Mr. Fordyce's efforts will be focused on the transfer of solar energy information from researchers to architects. He will, in this capacity, be involved in the development of audio-visual packages for distribution to AIA chapters. Informal reports will be forthcoming at intervals during this fiscal year.

Last year, John Holton of Perkins & Will, Architects, Engineers and Planners, Chicago, Ill., was selected as the first Architect-in-Residence. He has been active as a research resource to ongoing research projects within the

Center, has participated in two Off-Site programs, and has conducted individual research on natural lighting in buildings, working with other researchers in the Center and other parts of NBS. Liaison activities included conferences with the Directors of the Center, the Institute for Applied Technology, and NBS, as well as staff at Argonne National Laboratories and other research organizations.



Safety

SLIP RESISTANCE OF FLOORING

Robert Brungraber
Structures, Materials and Safety Division - 301-921-3851

Sponsor - National Bureau of Standards

The National Commission on Product Safety reported in 1970 that falls in the home each year kill about 12,000 and injure 6,000,000 people in the U.S.A. Slippery floors are listed as a large contributor to these figures. However, there are no well-established or generally accepted slipperiness standards for flooring. This project was initiated to provide information needed to commence the development of floor slipperiness standards. It includes a state-of-the-art study, evaluations of three existing test methods, and the preparation of plans for additional studies. Among these studies was the development of a dependable portable tester to measure a fundamental property that denotes slipperiness. This tester is being used to establish standards for flooring materials to control slipperiness.

The state-of-the-art was determined by searching the literature and by visiting several testing laboratories currently active in floor slipperiness studies. Preliminary laboratory evaluation of the three most promising test methods was completed, using three commonly used types of flooring material. Two of the three test methods (The Horizontal pull and the James) measure a fundamental property, coefficient of friction; however, both of them have serious limitations and need further development to make them reliable and portable.

The development of a reliable test method for field use is needed. This was performed by making a portable tester based on principles similar to those of a device now accepted by the American Society for Testing and Materials. A sensor suitable for simulating human skin on wet or soapy bathroom and swimming pool surfaces will be selected. Also simulated natural leather shoe soles are being investigated. A series of tests are being conducted to assess accuracy and precision of the portable tester.

RESTRAINT EQUIPMENT

Harold Steinberg
Product Systems Analyses Division - 301-921-3204

Sponsor - Occupational Safety and Health Administration

Each year falls injure or kill thousands of Americans. Some of these injuries are the result of falls experienced by workers whose jobs require that they perform their tasks many feet above the ground. The Occupational Safety and Health Administration (OSHA) recognizes the need for the development of valid performance standards for safety belts, harnesses, lanyards, lifelines, shock absorbers, grabbing devices, and other components of worker restraint systems. The American National Standards Institute, the Standard A10.14, currently under development, is likely not to satisfy OSHA's needs for several reasons. Therefore, OSHA is drafting its own performance standard for worker restraint systems. Even though the primary focus in the standard under development is the construction industry, it will lay the groundwork for related standards concerning safety restraint for lineman, tree-pruners, window washers, etc.

The study, which the Center is coordinating for the Center for Consumer Product Technology of the Institute for Applied Technology, will involve the application of systems analysis, product engineering, and human factors methodologies.

GUARDRAILS IN BUILDING STRUCTURES

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

Sponsor - Occupational Safety and Health Administration

The objective of this study is to formulate structural design criteria for guardrails. The study of guardrail systems will consist of: (1) an analysis of available information including codes, standards, worker anthropometrics and technical data; (2) a field survey of common types of installations, (3) experimental and analytical evaluation of guardrail loading and response and (4) preparation of structural performance criteria and a supplementary design guide. These performance criteria will be the basis for compliance of guardrail systems with respect to loading, geometry and resistance function.

To achieve the objectives of this project, the architectural research section of the Center will compile statistical information on the anthropometric features of workers, and will assist in the survey of prototypical installations in the field, including acquisition of existing information on guardrail failures.

Last year project tasks were drafted on the basis of problem areas identified through working sessions with the Occupational Safety and Health Administration. Also, a literature survey and preparations for testing were begun.

OUTDOOR STRUCTURES SAFETY

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

Sponsor - Consumer Product Safety Commission

Many injuries, result from accidents involving "outdoor structures," which include the following three product categories: (1) retaining walls, patios, terraces; (2) porches, balconies, open side floors, and floor openings; (3) handrails, railings, and balconies. This research is aimed at reducing the severity of these accidents.

The Center has developed a behavioral model for accidents with stairs and doors. This model will be extended to encompass outdoor structures. The Center has also developed techniques for investigating accidents through analyses of accident data, surveys of product usage, observations of human behavior in connection with product usage, and analyses of videotapes of such usage. These approaches will be used to identify where, when, why, and to whom accidents occur with outdoor structures and to recommend safety performance criteria as well as user guidelines.

SAFETY IN CONCRETE BUILDING CONSTRUCTION

Hai Sang Lew
Structures, Materials and Safety Division - 301-921-3851

Sponsor - National Bureau of Standards

This project is concerned with studies of two specific areas that affect safety in concrete construction. They are: (1) strength of falsework, which provides temporary support to a concrete structure during construction, and (2) rate of construction. As part of the first investigation, the study will determine the capacity of single-post shores as affected by field conditions. The second investigation will include the rate of strength and stiffness gain of concrete at early ages, evaluation of various methods of determining *in situ* strength of concrete, and development of a mathematical model of construction process to study parameters that affect the rate of construction cycle.

Among the accidents and failures that occur during concrete construction, nearly 60 percent are falsework failures, which usually happen at the time concrete is being placed. Because falsework costs can account for as much as 60 percent of the structural cost of cast-in-place concrete, early removal and reuse of the formwork and shores can decrease construction costs. Hence, for economic reasons, contractors want to remove forms and shore as early as possible. Such premature removals have caused serious failures or difficulties in the completed structures.

DOOR AND WINDOW SECURITY

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

Sponsor - National Bureau of Standards

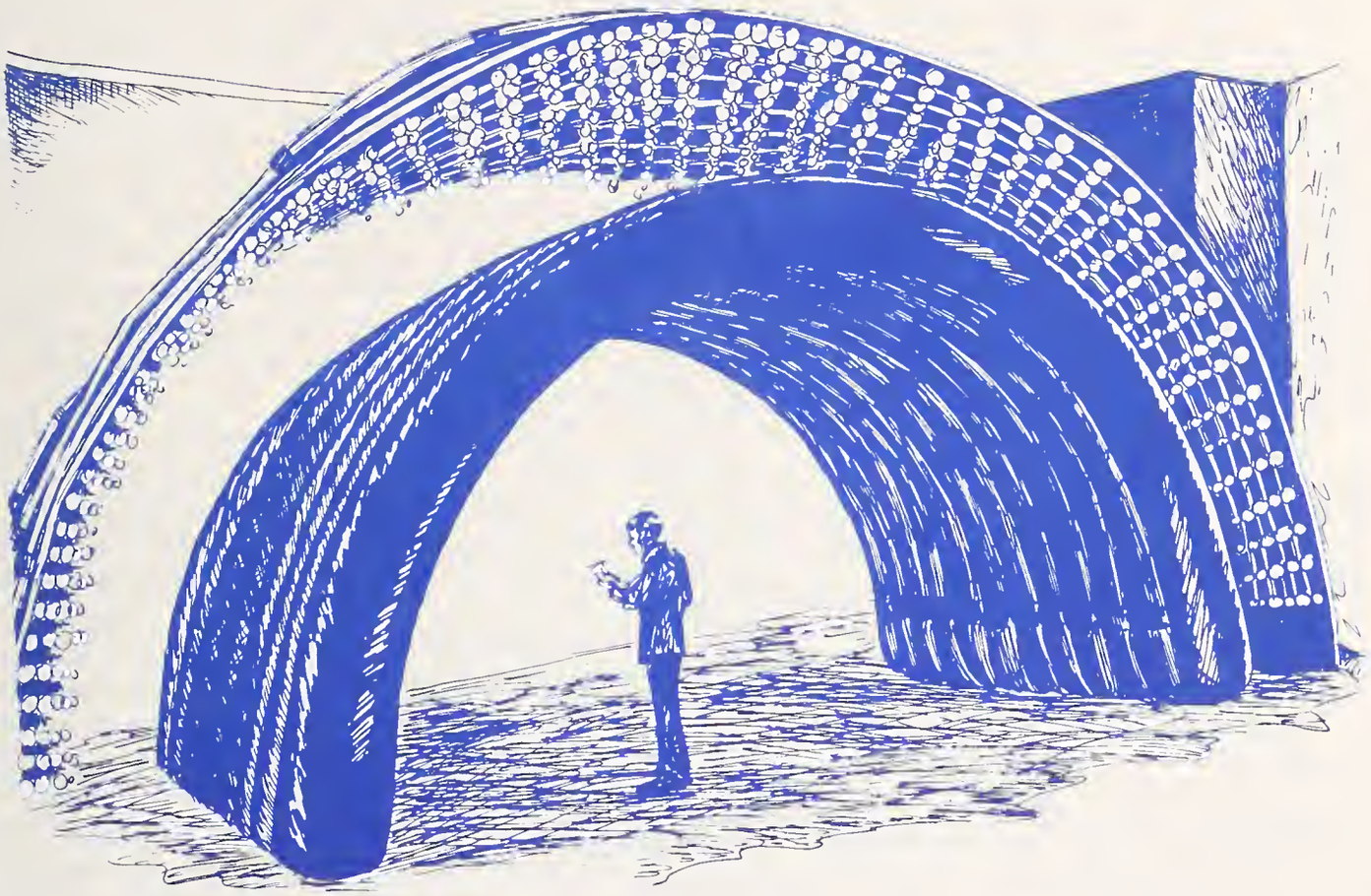
This project will propose criteria and test methods for residential and commercial doors and windows that will provide a known level of security against common burglary attacks. Approximately 90 percent of the burglaries are made through doors and windows; 80 percent occur at residences and small businesses. The losses to the resident and small businessman due to burglaries, which amounted to $500 million in 1970, are increasing every year. Justice Department statistics show that the large majority of burglaries are performed by the unskilled. This analysis emphasized that a relatively great decrease in burglary losses could be made by a relatively small improvement to doors and windows.

Typical doors, windows, and burglary tools, were instrumented so that the actual forces imposed, and resisted, could be measured. From these measurements, tests simulating burglary attacks were developed. The tests were designed so that the simulated attack would not be easily related to the actual attack method. Four levels of performance were identified as being related to the levels of skill and/or tools for door assemblies and three levels for window assemblies.

Last year, draft performance standards for these four levels of security were prepared for door assemblies and door components. A companion set of draft standards for window assemblies was prepared and forwarded to the sponsor.

It is expected that additional testing of hardware items, especially add-ons such as bolt latches, will be completed this year. Also a *Selection and Application Guide* for security hardware will be prepared.

Thermal Studies



THERMAL MEASUREMENT TECHNOLOGY

Tamami Kusuda
Building Environment Division - 301-921-3501

Sponsors - National Bureau of Standards; Department of Housing and Urban Development

Under this project, two major methods of thermal measurement and performance testing will be pursued. First, will be a new and improved guarded-hot-plate apparatus for use as an absolute method of measuring the thermal conductivity and thermal conductance of insulation and building materials. This apparatus is to replace the present apparatus (circa 1937) currently defined in the American Society for Testing and Materials Standard C177. Current methods and equipment are used as the national reference for supplying calibrated specimens to other laboratories in the U.S. and in several foreign countries and are used to measure materials for the National Bureau of Standards and other governmental agencies. The other task in the project is to develop and verify an automated technique to simplify the measurement of air infiltration sulfur hexafluoride (SF_6) dilution monitoring with respect to time. A computer-controllers system is being developed in cooperation with an independent research laboratory.

HEAT TRANSFER FOR THERMAL ENERGY STORAGE

Elmer Streed
Building Environment Division - 301-921-3503

Sponsor - National Bureau of Standards

One method of controlling the interior thermal conditions of buildings is to design the building thermal capacitance to conform to the ambient diurnal environment cycle for reducing peak heating and cooling load requirements. This program intends to develop analytical and experimental methods to predict and measure the transfer and storage of thermal energy for building heating and cooling applications using a wet sand bed.

Reduction in the consumption of expendable fuels for the heating and cooling of buildings is being pursued by the addition of thermal insulation, the reduction of air infiltration, and the use of total energy concepts. Past studies have shown the need for the use of thermal storage tanks with solar collectors, the desirability of using phase change materials, and the use of heat pipes to transfer the thermal energy from collectors to storage or from storage to the point of use. No heat-transfer studies have been reported on this specific application.

A review will be made of the characteristics and experimental procedures for determining thermal performance of water infiltrating sand bed. Analytical models describing the transfer and storage of thermal energy will be generated for use in simple building systems.

AIR INFILTRATION IN REACTOR CONTROL ROOMS

Charles Hunt
Building Environment Divison - 301-921-3512

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, the National Bureau of Standards

developed SF_6 tracer-gas technique 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 in two sample rooms. Control rooms at Beaver Valley, Pennsylvania and Brown's Ferry, Alabama, have been visited and specific measurements and sampling problems identified. Equipment has been assembled. The first measurements took place in September 1975, at Beaver Valley. Brown's Ferry is tentatively scheduled for March, 1976.

THERMOGRAPHIC MEASUREMENT TECHNOLOGY

Douglas Burch
Building Environment Divison - 301-921-3512

Sponsor - Federal Energy Administration

This project will develop a novel surface-heat-flow measurement technique, one that is needed for evaluating building thermal insulation. The use of thermographic techniques have thus far been limited to the measurement of surface temperatures and patterns of temperature, but there is no information on the use of this technique for measuring heat flow. This new technique would provide a way for non-destructive, large-scale, accurate heat-flow measurement.

The technique consists of developing a well-calibrated heat-flow reference pad whose surface emittance is matched with the building surface under observation. A suitable electronic link needs to be developed so that the thermographic image of the reference pad and the building surface are identical. This can be done by controlling the heat emitted (or absorbed) by the reference pad. The apparatus, which includes an integrator and digital display of the heat flux, is in the conceptual stage.

MEASUREMENT OF INDOOR RADIATION

James Hill
Building Environment Division - 301-921-3512

Sponsor - National Bureau of Standards

Under this project, new instrumentation for predicting human thermal comfort is being developed. Traditionally, thermal environments for human occupancy are evaluated by physical measurements of mean radiant temperature, air temperature, air velocity, and humidity. However, these do not directly permit consideration of the asymmetries and transient nature of thermal environments. Asymmetries are common in radiant environments and also arise from flows of cold or warm air impinging separately or simultaneously upon different sides of a human body. Spot-measurements of air temperature or air velocity cannot detect such asymmetries, nor do they permit consideration of their effects in ratings of environments for comfort.

Last year, a contract was issued to Dr. Theodore Benzinger for the development of a prototype resultant surface temperature (RST) meter. Basically, this is a device that produces heat at the same rate per unit surface area as does a human body. Whenever any factor of the thermal environment changes, the resultant surface temperature of the instrument must also change in order

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that the equilibrium between production and loss of heat can be restored. The RST meter was used in a segment of the field study on the National Bureau of Standards field test house to demonstrate the degree to which asymmetrical radiant conditions exist in a typical residential dwelling in winter.

FENESTRATION: THERMAL

Elmer Streed
Building Environment Divison - 301-921-3503

Sponsor - National Bureau of Standards

The approach to thermal-related aspects of windows is to relate artificial lighting and energy requirements with the solar thermal and day-light characteristics of selected window types. Data compatible with the Bureau's Load Determination Program (NBSLD) will be generated to permit simultaneous analysis of these parameters to determine the effect on total energy consumption of building types. These data will be used for additional analysis with economic, architectural, and psychophysical factors.

SEALED INSULATING GLASS

Mahn Hahn
Building Environment Divison - 301-921-3503

Sponsor - Department of Housing and Urban Development

Insulating glass may be prone to condensation of moisture inside its air cavity. To improve the performance of insulating glass, it was necessary to develop reliable testing procedures and instruments to see how dry the air space was before and after installation.

A cooperative effort among the Department of Housing and Urban Development, the National Bureau of Standards, the American Society for Testing and Materials, and industry has been undertaken to develop a new method for measuring the frost point of air between the glass, and to conduct round-robin tests on various temperature and humidity test cycles imposed on the insulating glass.

For this project, Dr. Mahn Hahn, a research associate with the Thermal Engineering Section, received an I-R 100 Award, an honor bestowed by Industrial Research magazine. The award is given annually to researchers, innovators, and developers responsible for significant new products. Dr. Hahn developed the apparatus for measuring the dew-frost point in insulating glass.

THERMAL PERFORMANCE OF THICK FIBROUS INSULATION

Elmer Streed
Building Environment Divison - 301-921-3503

Sponsor - National Bureau of Standards

The basis for the use of fibrous insulation with thicknesses of up to 35 centimeters (14 inches) is the assumption that the thermal conductance follows the basic Fourier Equation; i.e., the thermal conductance is inversely porportional to the thickness. However, in actual practice, the insulation is subjected to a dynamic environment with variations in relative humidity, temperature, and internal air movement, which could cause a deviation from this relationship. The design and specification of commercial low-density fibrous insulation is a compromise between reducing the conductance, economics, and the application requirement. Improved theoretical understanding of the

transfer phenomena especially relating to the internal air motion will help the manufacturer, design professionals and contractors better understand the in-service thermal properties and moisture condensation problems and moisture transfer.

This project will combine Bureau expertise in thermal conductivity measurements with university and industry experience to determine realistic heat transfer performance of building walls. Experimental verification of predicted performance is being performed and a comparison is being made with available data using the computer simulation technique.

INSULATION IN REFRIGERATED WAREHOUSES

Tamami Kusuda
Building Environment Divison - 301-921-3501

Sponsor - Tri-Services Committee

This project explored the feasibility of drying out wet insulation in cold-storage warehouse walls and ceilings by forced-circulation of warehouse air.

A majority of the nation's cold storage warehouses are experiencing difficulties in keeping the insulated wall from becoming water logged, because of continued water vapor condensation from outside. The method resulting from this project will contribute to large energy savings, in addition to a substantial reduction in warehouse deterioration.

The National Bureau of Standards apparatus for testing air, moisture, and heat transfer through walls was used for the conventional glass fiber type warehouse wall with a conventional vapor barrier. First the vapor barrier of the test walls was intentionally punctured in accordance with a predetermined pattern to bring the moisture into the insulation. Then, the cold side air was forced into the insulation by local, as well as overall, pressurization to see whether condensation in the insulation could be prevented or removed.

The test on a simulated fibrous glass insulation wall was completed. Separate tests on specimens of various insulating material such as cellulosic fiber, urea formaldehyde, and fibrous glass were also completed. It was found that the moisture condensation was prevented and any wet insulation was dried out by a slight increase in the pressurization of the cold side.

WALL STUDIES FOR THE AIR FORCE

Douglas Burch
Building Environment Divison - 301-921-3512

Sponsor - United States Air Force

This project will evaluate the effectiveness of several procedures designed to prevent damaging moisture accumulation in walls to which thermal insulation was added to reduce energy consumed for heating. Application of vapor barrier paints and venting the insulated cavity to the outdoor are examples. A survey of Air Force buildings will be conducted to identify three wall construction types that frequently develop moisture accumulation problems after being retrofitted. Laboratory and field studies will then be

conducted to examine the effectiveness of protective measures.

A full-scale wall section will be constructed in the laboratory and will be fitted into a test apparatus which will maintain the interior wall surface at 24 °C (75 °F) and 40% relative humidity and the exterior wall surface at a prolonged cold condition. The purpose of the tests conducted on the full-scale laboratory wall section would be to study in detail the moisture accumulation processes and the effects that occur in retrofitted walls.

RETROFITTING A DOMESTIC DWELLING FOR ENERGY SAVINGS

Douglas Burch
Building Environment Divison - 301-921-3521

Sponsor - Federal Energy Administration

The objective of this project is to measure the energy required for winter heating and summer cooling of a residential dwelling in an "as is" condition under a variety of weather conditions, and then determine the energy requirement after retrofitting.

During FY75, winter heating energy and air infiltration rates were measured and correlated with respect to outdoor conditions, so that savings in heating energy requirements could be determined. Then, three phases of the retrofit: caulking, adding insulation, and adding storm windows and doors, were performed. It was found that the steps taken to reduce air leakage (caulking, weather stripping, etc.) were not particularly effective in reducing air infiltration or heat loss rate because the test house was initially of tight construction, having air change rates from 0.4 to 0.75 air changes per hour before the caulking was done. The application of storm windows was found to have essentially no effect on the rate of air infiltration, but produced heating energy savings of about 24 percent. The addition of insulation saved an additional 28 percent. The total heating energy savings resulting from all the energy conservation measures was found to be 52 percent. The addition of insulation caused the rate of air infiltration to decrease by roughly 20 percent from its initially low value. At the end of the winter heating season, samples of wood siding, sheathing, and insulation cores were taken from house walls to determine moisture content. A comprehensive interim progress report was written. Awnings were installed on the house. The summer cooling energy requirements were measured for the retrofitted test house and compared to corresponding pre-retrofit values.

STANDARDS FOR REFRIGERATION COMPONENTS

William Mulroy
Building Environment Division - 301-921-3512

Sponsor - Army Natick Development Center

Since 1948, the National Bureau of Standards has responded to the needs of the Department of Defense's Natick Laboratories in the field of refrigeration and heating equipment. Information developed in this program was used for Natick's immediate needs and for generating and updating the standards of the American National Standards Institute, Inc., the American Society of Heating, Refriger-

ating and Air-Conditioning Engineers, and similar organizations. Methods of testing and ratings of performance characteristics were published and are now routinely used in the industry.

Recent work involved laboratory measurement of performance of refrigeration equipment. The goal was to obtain maximum efficiency and use of energy consumed without impairing reliability and effectiveness. The purpose was to improve energy efficiency and to develop equipment and systems, such as the heat pump, that deliver two to three times more cooling effect than the power supplied.

ENERGY CONSERVATION FOR FOOD SERVICE EQUIPMENT

William Mulroy
Building Environment Division - 301-921-3521

Sponsor - Army Natick Development Center

There are no existing test procedures for measuring the performance of food-service equipment under usage conditions. As a result, there are no data on the efficiency of different features or control methods for ovens, refrigeration units, or refrigerated structures—under part load, variable ambient, or simulated usage conditions. This project is developing test procedures to fill this void and is generating data to allow evaluation of different food-service equipment systems for energy consumption and life-cycle costing.

For example, normal refrigeration units are rated at full output at one fixed set of temperature conditions. This year, part load and variable ambient tests are being performed on refrigeration units. Several control systems are being used on this unit so that the response to variable conditions can be evaluated. Tests are also being performed to determine the efficiency improvement that could be expected by fitting larger than normal heat transfer surfaces. Studies will show the benefits to be obtained by employing demand defrost with careful sizing of the defrost heat supply.

Disaster Mitigation

FIRE AND LIVE LOADS IN BUILDINGS

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

Sponsors - General Services Administration; National Academy of Sciences

The objectives of this project are to collect fire load and live load data and to apply probabilistic models for predicting loads in office occupancies. The office building fire load and live load program involves surveys of rooms selected in a statistical manner chosen from buildings located throughout the United States. Based on surveyed room factors, interior finish, and the type, quantities and distribution of combustible contents and other live loads, a statistical model was devised to predict the fire and live loads to be expected in buildings.

The design of safe, economical structures requires consideration of loading and structural resistance. Although most building codes currently treat the design problems in a deterministic fashion, the trend in code development in the United States and abroad involves explicit consideration of the variability of these factors. Results obtained from this survey improve the understanding of the factors affecting loads in buildings and permit developing design values based on the probabilistic nature of the loading for incorporation in national model codes and consensus standards. This will contribute to improved building safety and provide one means for reducing life and property loss due to fires.

Survey techniques based on weight inventorying and data collection procedures were developed. Characteristics such as height, age, location, etc. of office buildings in the U.S. were determined and used to select a statistical sample of the buildings which were surveyed. Special data processing techniques and computer programs were developed for data analysis purposes. The final project report is available.

BUILDING PRACTICES FOR DISASTER MITIGATION

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

Sponsors - National Science Foundation; Defense Civil Preparedness Agency; National Bureau of Standards

Federal concern with building practice for disaster mitigation arises from major statutory responsibilities. Approximately 37 percent of all new construction is directly or indirectly Federally supported; good practices protect these investments and reponsibilities. The Disaster Relief Act Amendments of 1974 (P.L. 93-288) expanded these responsibilities requiring evaluation of the hazard potential of existing Federal facilities and Federal designation of appropriate reconstruction standards.

Working in cooperation with other agencies, the Center for Building Technology provides research results for implementation in Federal disaster mitigation programs.

Outputs include manuals of practice, recommendations for inclusion in codes and standards, and design criteria and procedures for improved building practices.

A report detailing procedures for evaluating the hazard potential of existing buildings was prepared. An evaluation of a new procedure for the design of earthquake resistant structures also was completed. A major effort was initiated

to develop comprehensive nationally applicable seismic design provisions. Representatives from 12 Federal agencies and 85 professionals from across the country are participating in the effort.

Presently the Center staff are working with the other Federal agencies in planning and coordinating work related to the provisions of P.L. 93-288. Specific research problems related to these provisions will be identified and implementation plans developed. The work will concentrate on the General Services Administration activities in evaluating existing Federal facilities and the Department of Housing and Urban Development's development of reconstruction standards. In consultation with the Defense Civil Preparedness Agency staff, their research needs relative to disaster mitigation will also be reviewed and procedures established for focusing laboratory work on required problem areas.

An implementation plan for laboratory research in the area of earthquake-resistant masonry construction will be developed based on results obtained from a future Center workshop. A report for use by design professionals will be prepared detailing the basic assumptions and concepts of the response spectrum approach to seismic design. Development of comprehensive seismic design provisions for buildings will continue and a first draft of the provisions issued for review and comment. A special workshop was held at the Bureau to provide an opportunity for Federal representatives to provide direct input to the final provisions.

SEISMIC PERFORMANCE OF BUILDING SERVICE SYSTEMS

Charles Yancey
Structures, Materials and Safety Division - 301-921-3475

Sponsor - National Bureau of Standards

This project will develop a program plan for establishing seismic performance requirements for building service systems in critical facilities (hospitals, communication centers, etc.) that must remain functional following the occurrence of earthquakes. The earthquake-resistant design of service systems and the performance of these systems in past earthquakes will be reviewed. Then a research plan will be developed for obtaining information required to improve this seismic performance and to ensure functioning after an earthquake.

The effort will involve: (1) the identification of critical service systems and functional requirements for these systems following an earthquake; (2) a review of the nature and extent of building service system's damage resulting from earthquakes; and (3) a review of seismic design procedures for building service systems and the data used to establish these procedures. Critical service systems and user requirements for these systems following an earthquake will be established by working directly with Federal agencies responsible for emergency facilities. These

requirements, [such as the length of time following an earthquake that the service systems must remain functional, dependence on external supply (water, power, gas, etc.) versus reserve on-site supplies, and others] provide the basis for performance criteria. Direct involvement of these agencies in the problem definition will ensure that the research plan developed is responsive to their needs.

The review of earthquake damage to service systems will be carried out in consultation with individuals involved in post-disaster investigations. Particular attention will be given to the limited data on failure modes for these systems and their performance following an earthquake. Needed experimental and analytical studies will be identified and incorporated in an overall research plan for building service systems.

DISASTER INVESTIGATIONS

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

Sponsors - National Bureau of Standards; Defense Civil Preparedness Agency

These investigations help define those construction practices where improvements would significantly reduce the loss caused by natural hazards and other extreme loadings. This study includes formulation of research plans directed toward obtaining data on the behavior of building components and systems and implementation of these results through consensus standards and codes.

Life and property losses from natural disasters are increasing annually. Studies have shown that improved standards and codes provide one means for substantially reducing these losses. For earthquakes alone, it has been estimated that improved standards could reduce total property losses incurred over the next 25 years by 10 percent.

Effective post-disaster investigations require considerable planning to ensure collection of the most significant types of data and full use of the learning opportunity provided by natural disasters. The Center for Building Technology's (CBT) effort will be coordinated with that of other Federal agencies concerned with collecting damage statistics and providing disaster assistance, such as the Defense Civil Preparedness Agency and the Federal Disaster Assistance Administration. It is anticipated that this coordination will lead to definition of a specific role for CBT in disaster recovery operations.

Liaison has been maintained with the National Science Foundation (NSF) activities related to post-disaster investigations. CBT staff has monitored a major project for NSF concerned with developing post-earthquake investigation procedures and provided extensive review of project reports. CBT staff has also participated in the Federal Interagency Disaster Mitigation Group and investigations were conducted following the collapse of a Federal office building in Florida and following foundation problems at the Department of Housing and Urban Development building in Washington.

WORKSHOP ON EARTHQUAKE RESISTANT MASONRY

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

Sponsor - National Science Foundation

The project is to organize and conduct a workshop on Earthquake Resistant Masonry Construction. In Part I of the workshop, investigators will discuss the objective and scope of existing research programs and present their findings to this date. Also included in Part I will be presentations by users of present design criteria for masonry structures. Part II of the workshop will consist of working groups who will assess ongoing research, research needs, and research priorities. The proceedings of the workshop will be published by the National Bureau of Standards.

HURRICANE EFFECTS ON PORT FACILITIES

Emil Simiu
Structures, Materials and Safety Division - 301-921-3475

Sponsor - The Maritime Administration

The purpose of this project is to contribute to the reduction of losses experienced by Gulf Coast and Atlantic Coast ports subject to hurricanes. This will be accomplished through the acquisition of wind speed data under actual hurricane conditions. Recommendations based on these data and on other available information will be made for the improvement of procedures used in the design of port facilities.

In FY75, a Center for Building Technology (CBT) team investigated conditions during Hurricane Carmen (August 1974). Two technical papers (for locations of hurricane winds and hurricane wind profiles) were published. Procedures for evaluating code provisions on design for winds were developed. CBT also gave assistance to port facilities in the requisition and installation of peak-reading anemometers.

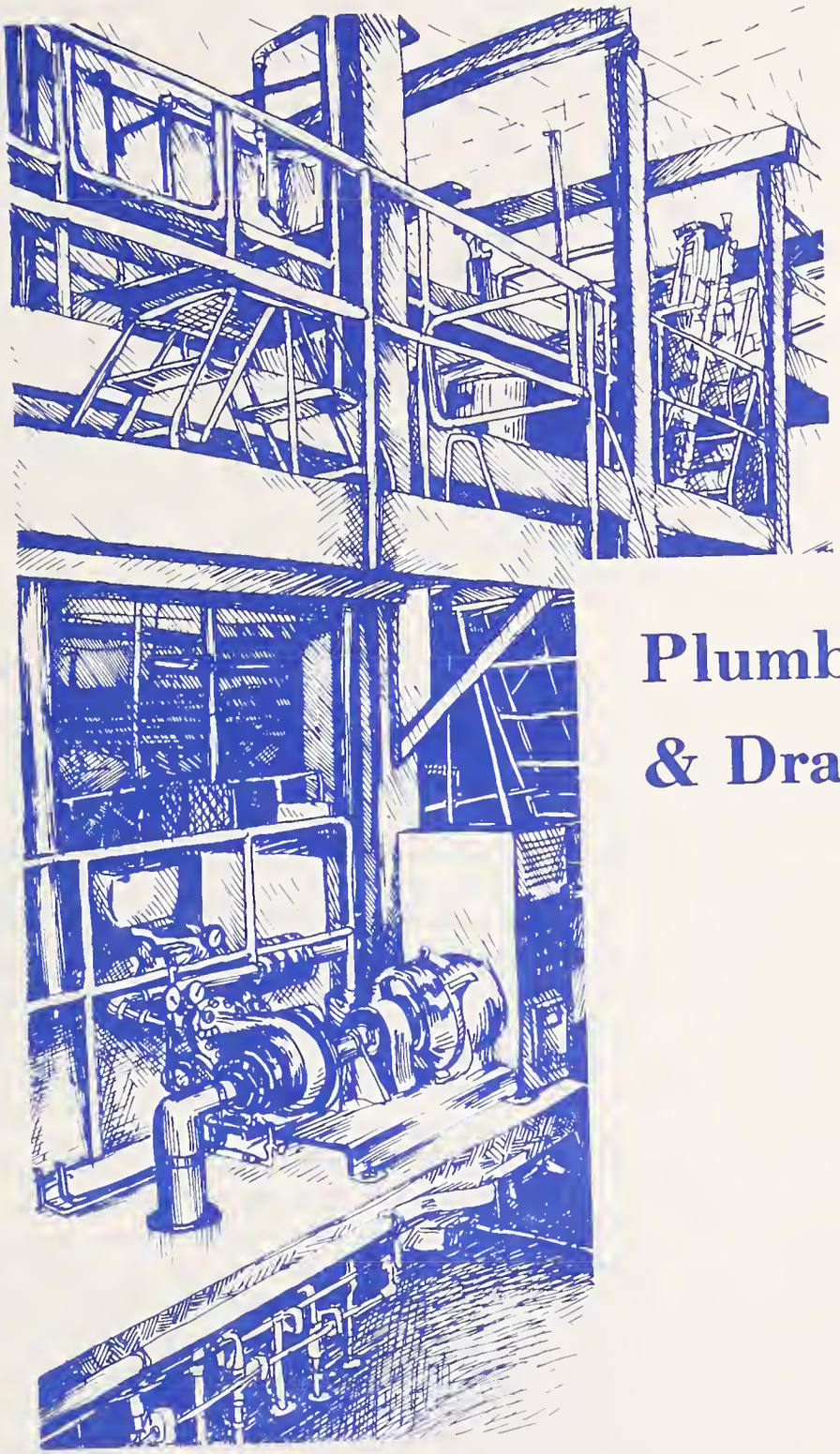
TORNADO-BORNE MISSILE VELOCITIES

Emil Simiu
Structures, Materials and Safety Division - 301-921-3475

Sponsor - Energy Research and Development Administration

This project will provide criteria for the safe and economical design of nuclear power plants that may be hit by tornado-generated missiles. This will be accomplished by estimating tornado-borne missile velocities, by obtaining pertinent data on drag and lift of typical missiles using wind tunnel tests, and by calculating peak and ejection missile velocities.

In FY75, a model for the motion of missiles in a tornado field was completed. A computer program for calculating and graphically representing wind speeds and trajectories was also developed. This year the Center plans to further develop the results of wind-tunnel studies along with a list of drag and lift coefficients. The Center also will prepare a report for the sponsor, *Tornado-Borne Missile Velocities*, including a critique of present approaches, the computer program, and results.



Plumbing & Drainage

STUDIES OF REDUCED-SIZE VENTING

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

Sponsor - Tri-Services Committee

This project, featuring a planned field study, was established to validate and improve existing, laboratory-based design criteria for reduced-size venting.

Plans for four types of military housing units were modified in accordance with existing criteria for reduced-size venting as recommended by the Center. These units were fitted with instrumentation and a data acquisition system to measure the most significant parameters that determine service loads and hydraulic/pneumatic functional performance. Such parameters include: seal retention in idle traps; blow-back/bubbling in idle traps; peak penumatic pressure excursions in vents adjacent to idle traps; water depth in building drain; air flow rates in vents; and time and spatial distribution of discharge operations of the principal load-producing fixtures and appliances.

The Center has recommended certain criteria for the design of reduced-size venting systems in one- and two-story housing units, and has suggested that further economies and greater reliability may be possible based on (1) service data on load patterns, and on actual hydraulic-pneumatic performance in occupied buildings, and (2) data from selected laboratory tests designed to contribute to a more generalized, computational approach than is now possible with present design criteria.

PLUMBING SYSTEMS DESIGN CRITERIA

Lawrence Galowin
Building Environment Division - 301-921-3293

Sponsor - National Bureau of Standards

The Center for Building Technology (CBT) plans to upgrade present methodology for the hydraulic design and evaluation of plumbing systems, with an orientation to performance concepts. The work is needed to provide a scientific basis for criteria and evaluation techiques that will: (1) speed acceptance of innovative designs, and (2) reduce consumption of materials, energy, and water. The results will significantly contribute to effective input in national and international standards, and in the model codes and specifications used by other governmental agencies. Mathematical models, reproducible test methods, and user-oriented performance criteria will be developed from laboratory experimentation. This information and computer aids will be used to predict the hydraulic performance of a range of designs.

During FY75, further progress was made to complete the CBT plumbing research laboratory. Of particular significance was the acquisition and installation of a modern display and test-load controller system. The design, fabrication, and installation of instruments and components was essentially completed, comprising a specially designed 5-story single-stack drain-waste-vent system with building sewer and submergence simulator. For the U.S. counterpart commission to Conseil International du Batiment

(CIB) W62, Water Supply and Drainage for Buildings, work involved preliminary efforts to define a number of national issues and research needs, and to plan for the 1976 CIB W62 Symposium to be held in Washington.

Liaison and review activities have continued on the P.L. 480 program on Water Conservation measures in Plumbing (at the Standards Institution of Israel), on the P.L. 480 program on hydraulic performance of innovative high-rise sanitary drainage systems (at the Central Building Research Institute of India), and on the Complementary Research Agreement between CBT and the Building Research Establishment (BRE), (United Kingdom) on building drainage. Progress was made in organizing a program to introduce the performance approach as a complementary activity in the American National Standards Institute, Inc. A40 project on the National Plumbing Code.

FY76 plans are to issue reports on preliminary tests on stack dynamics and calibration of fixtures, to complete exchanges under prior agreement with BRE, and to install several pieces of equipment required to support research work. Among these are automatic hydraulic terminal control devices (e.g., digital valves and associated electronics), additional signal conditioners for strain gauges, pressure transducers, a low-range load cell, transparent fittings and pipe, pressure overrange switch-gauges, water-depth transducers, and bubbling transducers.

MEASUREMENT TECHNOLOGY: UTILITY LOADS

Richard Grot
Building Environment Division - 301-921-3293

Sponsor - National Bureau of Standards

This project will provide new or improved instrumentation for research activities related to water usage, energy consumption, and plumbing phenomena. For many research undertakings, instrumentation is either not available, not automated, or excessively expensive. An increasing emphasis on field measurement of energy and water parameters requires low-cost, automated data acquisition. Similarly, the proper functioning of the building electrical systems laboratory and the plumbing tower require special purpose instrumentation.

Since last year, the prototype field-portable data acquisition system for monitoring water usage in residences has been assembled. The compact system will measure and record the signal output of flowmeters, flow switches, and temperature transducers in both digital and analog form. A plumbing fixture trap depth sensor and signal conditioning package has been designed, constructed, and laboratory tested. This sensor is capable of measuring trap depth retention to within 5 mm and indicates that water is flowing through the trap. Electronic instrumentation has been designed, constructed and tested for the encoding and recording of discrete events, and for the totalizing of pulses

from water meters, electric meters or gas meters, to measure the total quantity of water, electricity, or gas consumed in an interval of time. A small propeller anemometer and corresponding signal conditioning cards have been constructed for measurement of air flow in ducts. This instrumentation has been assembled, along with the necessary control logic cards, in two types of data logging packages; one applicable for measuring water and drainage usage patterns and evaluating innovation in plumbing systems and the other for determining energy usage patterns of household appliances.

During this year, instrumentation for interfacing the building electrical systems laboratory and the plumbing tower to the Center's mini-computer are being assembled and tested. Emphasis is placed on modifying commercially available data logging equipment and the Bureau-developed equipment to the specific needs of these laboratories. Several schemes for rapidly scanning and storing two to five second bursts of data for later transmission or recording at slower rates are being examined.

VETERAN'S ADMINISTRATION HOSPITAL PLUMBING CRITERIA

Lawrence Galowin
Building Environment Division - 301-921-3293

Sponsor - Veteran's Administration

This project provides for the application of simplified plumbing drainage concepts in hospital design to reduce the quantities of materials used and to increase the efficiency of space use, particularly in the modernization of old hospitals. Provision is made for the transfer of existing criteria and research-based design recommendations to be used in the development of new criteria through planned laboratory tests, and for a field performance evaluation to confirm the adequacy of the design criteria and to demonstrate the benefits achieved.

The findings are expected to be of particular interest to the Veteran's Administration (VA) in planning for future medical care services, and are also expected to be of significant interest to other governmental and private-sector agencies concerned with providing medical care services emphasizing spatial efficiency in design. The study approach is as follows:

Phase 1 - Review existing VA criteria and plumbing plans and specifications in the light of recently developed criteria and performance data for simplified designs for drain-waste-vent systems, with recommendations as to applications and benefits in selected VA building programs.

Phase 2 - Full-scale or critical-component tests in the Center's plumbing research laboratory, or at

some other appropriate laboratory having facilities suitable for the acquisition and analysis of data from complex dynamic fluid flow processes.

Phase 3 - Field demonstrations in one or more VA hospitals, involving measurements of key hydraulic performance parameters and load-patterns at selected points in the building.

TECHNOLOGY OF WATER CONSERVATION

Lawrence Galowin
Building Environment Division - 301-921-3293

Sponsor - National Bureau of Standards

Inadequate supplies of water can affect the health, safety, and welfare of the entire population and can cause severe economic repercussions in industry and agriculture. Water demands in dwellings have historically expanded, and the introduction of new water-consuming devices imposes new loads on the water supply system as well as increases the waste-water treatment loads. New program developments are under way to expand the water resource base as the availability of watershed developments vanishes; e.g., the Environmental Protection Agency's program in waste-water reprocessing to potable quality for recycling. Alternate strategies can be developed to satisfy the water demand requirements. Two examples are: (1) matching the supply water quality to the usage requirement with dual-pipe supply systems in buildings, and (2) establishing water conservation practices through technological innovation with reduced water flow systems and fixtures. This project is limited to the investigation of approaches for developing standard practices of water conservation by built-in technologies.

The broad objectives of developing water conservation attitudes and equipment practices that reduce water consumption are to be approached in a step-by-step manner. This initial task is to conduct studies of built-in water supply distribution systems and fixtures as follows: to determine the measure of functional adequacy for several proposed systems that conserve water; to develop protocols of testing methods for evaluation; to conduct tests for realization of water savings; and to reduce energy consumption and impact upon the water quality delivered.

At present, there are no standards for measurement and evaluation of claims of water-conservation practices; e.g., reduced flush toilets do not require verification of claimed reduced flow per flush. In installations of blended or tempered hot water single-pipe water supply distribution systems in dwellings the patterns of usage may mitigate the water and energy savings. Innovative approaches for methods of water conservation are marketed with claims of water savings which are not backed by reliable tests. There is a need for uniformity, particularly with respect to a normal base load or patterns of usage.

During this year, the Center is selecting representative samples of typical classes of water conservation single-pipe blended water systems for inclusion in the test program, preparing protocols for test methods, reviewing baseline standards of comparison from demand curves, and formulating procedures to assess the water quality discharge at the tap.

COMPUTER EVALUATION OF BUILDING PLUMBING SYSTEMS

Lawrence Galowin
Building Environment Division - 301-921-3293

Sponsor - National Bureau of Standards

This project was intended to apply computer-aided graphics developments to the evaluation of various building services. High-speed computers and computer graphics were used to physically describe the installation within the building. The information required to dimensionally describe the building and empirical data to describe loads, fixture locations, system designs, and use patterns were catalogued and processed to produce standardized inputs for computer programs under development for evaluating building plumbing systems at the National Bureau of Standards and Building Research Establishment in the United Kingdom (as well as other studies conducted elsewhere).

In FY75, the Center completed the interfacing of the Tektronix plotting routines into the minicomputer; operational status was attained with display cathode ray tube peripheral. This system provides geometric and graphic display with hard copy available on command.

NATIONAL PLUMBING CODE

Lawrence Galowin
Building Environment Division - 301-921-3293

Sponsor - National Bureau of Standards

The American National Standards Institute, Inc. (ANSI) A40 National Plumbing Code was last revised in 1955 and is in serious need of upgrading. Participation on this standards committee allows implementation of the Center's research results, especially in the area of performance standards, and also helps to identify future research needs. While extensive input will be made to the development of the specification portion of the standard, the major opportunity for the Bureau appears to lie in the application of the performance approach to plumbing standards.

A40 and its sub-groups currently are revising the A40 Plumbing Code along two different tracks: traditional specification code lines, and a performance type document. With extensive input from the Bureau, considerable progress was made on the drafting of the specification document. Three meetings of the A40 committee were attended by the Bureau staff. It is anticipated that the specification document will be submitted to the ANSI consensus process in early 1976. Activity associated with the development of the performance-type optional code will continue during the year.

LIQUID WASTE MANAGEMENT RESEARCH

Richard Symuleski
Building Environment Division - 301-921-3293

Sponsor - Department of Housing and Urban Development

This project will provide technical support in monitoring the performance of a Department of Housing and Urban Development contractor who is developing a waste-water management manual for new housing. Responsibilities will include review of all documentation produced by the contractor. The objective is to ensure that the manual developed will be useful to the building community and to the general public.

CRITERIA FOR PIPING MATERIALS

Lawrence Galowin
Building Environment Division - 301-921-3293

Sponsor - Department of Housing and Urban Development

Criteria to support the acceptance of innovative piping materials are urgently needed. In particular, thermoplastics have become attractive in terms of first cost and convenience of assembly; but on the other hand, the product standards do not directly address certain characteristics critical to safety or durability.

In this project, a review of existing standards and industry data was carried out to establish the user-related measures of functional performance, of health and safety, and of durability for installed piping systems. Laboratory tests were conducted to examine the critical performance characteristics not specifically covered in the standards, and from these data suggested performance criteria and test methods were drafted as supplemental to, not instead of, the existing product standards. The approach will produce broad evaluation criteria that are not dependent on the particular materials; however, the performance characteristics of the material may determine which criteria are critical and hence, which test methods need to be developed.

In FY75, laboratory work was completed, supplementing earlier work. This work was concentrated mainly in the areas of fire performance and thermal properties, and involved a broadened range of thermoplastics materials.

Some of the concerns relating to the use of thermoplastic piping in above-ground residential plumbing systems can be significantly reduced or eliminated by a more careful application of existing knowledge in design, installation, and inspection. In other areas, e.g., fire safety, environmental stress cracking, and quality of joints, recommendations to develop suitable evaluation methods are contained in the reports already issued and in preparation.

SERVICE SYSTEMS DATA PROCESSING

Daniel Rorrer
Building Environment Division - 301-921-3521

Sponsor - National Bureau of Standards

To date, the computer software needed in support of the Building Environment Division projects has been purchased from project funds. Such software serves a general purpose function for experimental control, data acquisition, reduction, and analysis. However, lack of a common support base for software development has led to many

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specialized programs. New general purpose programs are needed, which will enhance laboratory capability and ease the use of instrumentation for plumbing, data-acquisition systems, and conversions for precomputer analysis of laboratory and field data. This project will satisfy these needs and provide for regular maintenance of minicomputer software.

Mobile Homes

MOBILE HOMES AND RECREATIONAL VEHICLES

James Gross
Office of Building Standards and Codes Services - 301-921-3447

Sponsors - Department of Housing and Urban Development;
National Bureau of Standards

The Center for Building Technology (CBT) has for many years been represented on the American National Standards Institute, Inc. (ANSI) A119.1 Committee on Mobile Homes, which develops the standard for mobile homes. This involvement was given increased emphasis about three years ago when CBT decided to designate ANSI Committee A119 as a high priority standard activity. This resulted in an increased level of participation on the Sectional Committee on Mobile homes and the Sectional Committee on Mobile Home Installation and their task forces. It eventually led to CBT's being invited to join the A119 Correlating Committee, which oversees all mobile home and recreational vehicle standards development. The ANSI A119.1 Standard for Mobile Homes has gained wide acceptance with 46 States using the standard in their mobile home regulatory program. The Department of Housing and Urban Development, in developing the mandatory Federal Mobile Home Standard, has utilized a large part of A119.1.

The active CBT participation in the ANSI A119 Committee has provided a means for transmitting the results of mobile home research to interested parties in industry, government, and consumer groups.

ENERGY USE IN MOBILE HOMES

Bradley Peavy
Building Environment Division - 301-921-3503

Sponsor - Federal Energy Administration

This project is concerned with energy utilization in heating and cooling mobile homes. The test plan includes the instrumentation and measurement of the thermal performance of a new, furnished mobile home, built to 1974 American National Standards Institute, Inc. A119.1 standards, in the large Center for Building Technology (CBT) environmental laboratory. The work in CBT will be supplemented by contract research by Purdue University to determine the efficiency of heating and air-conditioning systems used in mobile homes.

DOW RESEARCH ASSOCIATE PROGRAM: ENERGY CONSERVATION IN MOBILE HOMES

Paul Achenbach
Building Environment Division - 301-921-3637

Sponsor - Dow Chemical Company

The National Bureau of Standards has entered into an agreement to supervise and administer, on behalf of the Dow Chemical Co., a research associate program related to energy conservation in mobile homes. The effort is directed toward the formulation of economically feasible performance requirements, criteria, and test methods to minimize energy requirements of mobile homes. The research associate activities will be complementary to present Center activities in mobile home thermal performance, structural behavior, and materials of construction.

COORDINATING FIRE SAFETY RESEARCH IN SINGLE-FAMILY RESIDENCES AND MOBILE HOMES

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

Sponsor - Department of Housing and Urban Development

The Center for Building Technology is coordinating with the Center for Fire Research two fire safety research projects. The first seeks to develop meaningful test data and design criteria for fire safety in mobile homes. Fire safety appears to be a special problem in mobile homes which comprise more than 40% of new home construction. Technical information on certain fire safety aspects is lacking and is needed to improve the current mobile home standard National Fire Protection Association (NFPA) 501 B American National Standards Institute, Inc. (ANSI) 119.1 and a new Federal mobile home standard. This kind of information is needed by fire departments and building code officials, by government agencies and by the mobile home industry.

The basic approach to this research involves (a) air movement, ignition, detection and fire growth studies on used and new mobile homes and (b) laboratory tests on materials. Subsequent phases will address the contribution of furnishings and the effectiveness of suppression systems on minimizing fire severity. Four moible homes will be included in this test program.

In FY75, a series of air movement tests were performed to determine the significance of air flow patterns on potential fire growth. A series of 28 full scale kitchen cabinet tests were conducted to evaluate the potential fire hazards in the kitchen area and to develop appropriate design rules to minimize these hazards. A series of 9 full scale corridor tests were conducted to evaluate the relative performance of a variety of interior finish materials. The information provided by the testing in FY75 was also transmitted to the Department of Housing and Urban Development (HUD) as input to the HUD effort to prepare a national standard for mobile homes.

The second project will define the fire exposure from the combustible contents of rooms in single-family dwellings and mobile homes. Recent data is not available on the type and distribution of fire combustible contents in residences. Adequate evaluation of the effects of fire on the buildings by fire protection engineers, building designers and code officials, is not possible.

Information will be collected by surveying the combustible fire loads in a statistical sampling of homes and apartments, and by using analytical methods to define the limits of fire exposure due to the burning of these combustibles under a range of fire growth conditions. The assembled data will provide the fire load input to analytical models of fire growth and severity which will be used to generate fire exposure curves for residences and mobile homes.

WIND FORCES ON MOBILE HOMES

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

Sponsor - Department of Housing and Urban Development

The project will lead to a better understanding of the wind characteristics at heights up to 10 meters and the relationship between these characteristics and wind loads on mobile home structural components and anchoring systems. Task No. 1 will involve the direct measurement of wind speeds, surface pressures, lift, drag and overturning movements on a full-scale mobile home. Task No. 2 will involve the study of load-deformation relationships and the behavior of structural components at or near ultimate load capacity by application of simulated wind forces.

The project will include both field and laboratory studies of wind forces and the response of a full-scale mobile home to these forces. A 3.6 m (12ft) x 20.3 m (60ft) unit will be fully instrumented to measure internal pressures, external surface pressures and certain racking deformations. The unit is mounted on a rigid bed which can be rotated to alter the relative wind direction and which is fitted with sensors such that life, drag and overturning moment can be measured directly. Corresponding measurements of the mean and fluctuating components of the oncoming wind are also being measured. Detailed studies of load-deformation characteristics and performance of structural components at near ultimate load capacity will be carried out in the National Bureau of Standards structures laboratory using hydraulic rams to apply loads which are similar in amplitude and frequency content to real loads associated with extreme winds. Finally, the information collected from these studies will be used to draft recommendations for mobile home wind load design requirements.

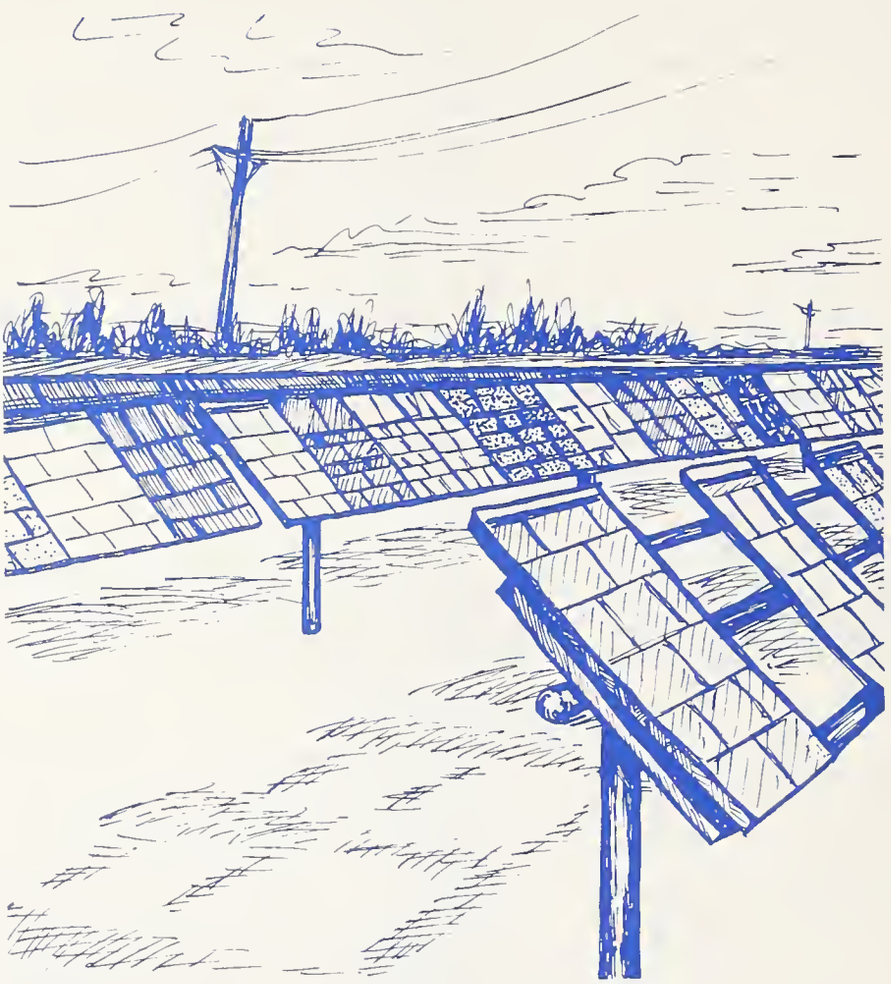
STORING THE DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT'S DISASTER MOBILE HOMES

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

Sponsor - Department of Housing and Urban Development

The Center for Building Technology is providing the Department of Housing and Urban Development (HUD) with recommendations on the most cost-effective method of storing mobile homes at storage centers located around the United States for use as emergency temporary housing for victims of future natural disasters. HUD is now storing 8,500 mobile homes from the Hurricane Agnes stockpile and they want to ensure that deterioration of these units be kept to a minimum, along with storage and upkeep costs. Specific concerns are water penetration; rodent, dust and insect penetration; in-transit damage; and humidity damage. The project includes visits to mobile storage centers around the United States to evaluate procedures and to assist in the development of recommendations for alleviating the problem areas.

Materials



DURABILITY PREDICTION METHODOLOGY

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

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 by improving the technology of durability prediction of building components and materials. It involves the developing and applying a general methodology for durability prediction, maintaining seven natural exposure stations, performing tests to provide information about the relationships between the effects of natural weathering and accelerated laboratory weathering, and performing a complementary program with the Canadian National Research Council (NRC) to develop international standards for natural weathering of building materials.

A general methodology for durability prediction was developed and is being improved by application and by participation of the American Society for Testing and Materials (ASTM). The methodology provides the framework for both natural and accelerated tests performed at the Bureau and in the complementary program with the Canadian NRC. The methodology will be submitted to ASTM as a recommended practice, and its application will provide information about the relationships between the effects of natural and accelerated weathering. In the complementary program with NRC, candidate materials proposed for use as standards for exposure to ultra-violet radiation and sunlight will be exposed on the NBS and NRC outdoor exposure racks and in laboratory accelerated weathering equipment. Changes observed in the specimens in laboratory tests will be compared with those obtained in the field. In addition, the linearity of the responses to radiation will be investigated in both sets of specimens and the derived calibration curves compared to establish which, if any, of the candidate materials are suitable for use as radiation exposure standards.

INORGANIC BUILDING MATERIALS

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

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 in the use of building materials. 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 are also investigated.

In FY75, the following work was completed: (1) the mechanical properties and fracture mechanic properties of polymer-impregnated mortars were compared with those properties of unimpregnated mortars; (2) the residual porosities of polymer-impregnated hardened cement pastes and mortars were measured by mercury intrusion and nitrogen condensation; (3) a study of the effect of the geometry, concentration, and fiber material on the mechanical properties of fiber-reinforced mortars; (4) a manuscript on the performance of concrete at high temperatures was prepared; and (5) the microstructure of hardened cement paste was investigated by scanning electron and optical microscopy.

For FY76, the plans are as follows: (1) investigate the effects of specimen size and temperature on the relationship between stress intensity and rate of crack growth for polymer-impregnated and unimpregnated hardened cement pastes, mortars and concretes; and (2) study the microstructure of impregnated and unimpregnated hardened cement pastes and mortars by mercury porosimetry and scanning electron and optical microscopy and relate microstructure to performance.

ORGANIC COATINGS

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

Sponsors - Tri-Services Committee; 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 one 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.

Individual factors, such as humidity, solar radiation, corrosive environments, and thermal shock, which affect the durability of exterior coatings on various substrates, will be examined by laboratory tests. Test methods will be developed to determine performance characteristics that will be applicable to the American Society for Testing and Materials (ASTM) standard test methods, Federal Test Method Standard No. 141, and coatings specifications.

In FY75, a study of the performance of exterior coatings containing non-mercurial fungicides was completed. Preliminary studies on the effects of sulfur dioxide on main-

tenance coatings were also completed. In cooperation with ASTM, the Center participated in the evaluation of test methods for gloss and reflectance measurements, stain removal, analysis of heavy metals in low concentrations, and standard atmosphere conditioning.

AVERSIVE COATINGS TO REDUCE LEAD-PAINT POISONING

Max Tryon
Structures, Materials and Safety Division - 301-921-3441

Sponsor - Department of Housing and Urban Development

Aversive coatings that will discourage children from eating lead paint flakes are being considered by the Department of Housing and Urban Development as a possible deterent to the ingestion of paint. Since little is known about the ability of aversive coatings to retain their deterent properties over long periods of time, tests for the durability of aversive coatings must be developed and applied in their evaluation.

For each aversive coating selected for evaluation, three main tasks will be carried out: the development of a suitable analytical procedure for determining the quantities of the essential aversive ingredients; a study of extraction procedures for the essential aversive materials using laboratory samples containing known amounts of the materials; and an evaluation of its ability to be retained on laboratory-prepared painted surfaces after artificial weathering and repeated washing.

NONTOXIC YELLOW MARKING PAINT

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

Sponsor - Department of Transportation

Until recently, the most widely-used yellow paint pigment was lead chromate. With the restriction of lead pigments for use 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 the project is specifically concerned with non-lead pigments for marking paints, the knowledge gained will provide knowledge about non-lead yellow pigments for use in paints and buildings.

In this project, information on non-lead yellow pigments and their use in paints has been obtained from the literature and from pigment and paint manufacturers. Marking paint formulations using non-lead pigments are being evaluated in the laboratory for such properties as light fastness, hiding power, abrasion resistance, adhesion, and durability. Painted specimens will also be tested for resistance to various climatic environments by exposure at outdoor exposure sites and for usefulness as marking paints in field tests on highways. Performance criteria for non-lead yellow marking paints will be recommended in the final report.

UNDERGROUND PLASTIC PIPE SYSTEMS

Tamami Kusuda
Building Environment Division - 301-921-3501

Sponsor - Tri-Services Committee

This project will evaluate new underground pipe systems that have not met the existing Tri-Services criteria that the pipe insulation be driable, drainable, and air testable. The evaluation objective is to determine if these non Tri-Services systems will stay dry under specified test conditions, particular to each pipe system.

The existing Tri-Services criteria are applicable only to a conduit system which has air space between the insulation and the conduit. There are, however, many new underground systems, especially plastic pipe systems, which do not have the air space. The representations are that these systems are so completely water-tight that there is no need for the requirement of drainability, driability, and air testability. It is in the interest of Tri-Services, as well as other government agencies, to verify these claims.

Each different underground pipe system requires different testing procedures. Appropriate tests will be devised for each selected pipe system to see how reliable it is and to determine if the water, once brought in, can effectively be removed by the circulation of air or other inert gases.

During this fiscal year, dynamic boiling tests on one of non-Tri-Services's systems were completed to clarify the failure mechanism. Also completed were moisture migration tests of a chilled water pipe insulated by hydrophobic powder. Thermal performance tests are in progress for a new, but non-air-testable, asbestos conduit system.

In FY76, a facility to conduct boiling tests of calcium silicate insulation with new fibrous glass binders (instead of asbestos binders) is being constructed to test several commercial pipe insulations. Dynamic boiling tests on a new non-air-space conduit system will be completed.

JOINTS IN PLASTIC PIPES

Max Tryon
Structures, Materials and Safety Division - 301-921-3441

Sponsors - Tri-Services Committee; National Bureau of Standards

Plastic pipes are finding increasing use for transmitting natural gas, sewage, and steam condensate at military installations. Unfortunately, there have been numerous failures of plastic pipe systems that have passed acceptance tests. Because many of the failures have been attributed to faulty joint construction, there is an important need for reliable, non-destructive tests for joints in plastic pipes.

Using plastic pipe joints of varying quality prepared in the laboratory, potential non-destructive test methods were evaluated for their ability to identify faults and for ease of use. Non-destructive test methods investigated included thermal conductivity and thermographic scanning techniques.

Plastic pipe joints containing known flaws were prepared. Two thermal methods were tested for their ability to detect the flaws from local differences in surface temperature when the pipes were heated internally with

warm water. The scanning cameras could detect all the flaws but liquid crystals only detected the largest ones.

BUILDING JOINT SEALANTS

Arthur Hockman
Structures, Materials and Safety Division - 301-921-3497

Sponsor - Tri-Services Committee

Premature failure of sealants in buildings results in damaged interior and costly repairs and maintenance, as well as loss of heat. The need for durable sealants is critical because of curtain wall designs, large thin panels, modular construction, and use of high expansivity materials. The large dimensional changes that occur in buildings demand better sealants.

In this project, the sponsor is kept informed of the latest developments on sealant test methods, specifications, and practices. This information is obtained by laboratory and field evaluation of new sealants and by participation in standards-making organizations, e.g., American Society for Testing and Materials (ASTM), American Concrete Institute, etc. Cooperation with architects, government agencies, producers, organizations such as the Adhesives and Sealants Council, National Paint and Coatings Associations, universities, and foreign groups relating to sealant research is maintained; consultation is continuously provided to the sponsor.

In FY75, the Center completed the evaluation of several samples of the new ± 50% class of sealants and recommended the inclusion of such a class in appropriate Federal and ASTM specifications. A second draft of a Recommended Practice for Chemically Cured Sealants was completed for ASTM ballot. A third round-robin study of Peel-Adhesion tests and first drafts of revisions of Federal Specifications were also finished.

The Center is performing the following during FY76: (1) revise and upgrade three 5-year old ASTM Standards on joint sealants; (2) develop the ASTM Specification for chemically cured sealants to replace the American National Standards Institute, Inc. A116.1; (3) expose sealants to accelerated weathering and to natural exposure; (4) plan complementary program with the National Research Council, Division of Building Research, Canada.

WATERPROOFING PRACTICES MANUAL

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

Sponsor - Tri-Services Committee

Water damage to military building installations and to their contents presents a continuing problem. A manual establishing standard waterproofing practices will benefit all military services by helping to ensure the adoption of proper practices. The manual developed under this project will include sections on environmental exposure, types of substrate (including construction details), classes of waterproofing products, methods of surface preparation and coating application, and life-cycle costing related to the waterproofing of buildings.

BUILDING STONE PRESERVATIVES

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

Sponsor - National Park Service

Faced with evidence of serious stone deterioration in historic buildings, the National Park Service asked the Center to evaluate commercial stone preservatives and to develop performance criteria. The criteria will aid the selection of materials for the preservation of national monuments.

Fifty-seven recommended stone preservatives were collected and subjected to tests. The effects of heat, freezing and thawing, water, ultraviolet radiation, salt, and sulfurous acid solutions on preservative-treated stone were evaluated in a specially constructed chamber and also in a series of separate tests. The results, including recommended criteria for selection of stone preservatives, will be published in a National Bureau of Standards Building Science Series report.

PERFORMANCE OF ROOFING

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

Sponsor - National Bureau of Standards

For over 70 years, bituminous built-up roofing has been specified by prescriptive specifications. Little attention has been given to the mechanical and physical properties of the membrane. Criteria are needed that quantitatively state the level of membrane performance. Producers of roofing products also need criteria for the types of products they manufacture.

Twenty performance characteristics of built-up roofing membranes were identified. They 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. Test methods are being developed and applied to the measurement of the performance characteristics that were identified. Contributions to the development of standards and test methods are being made through participation in the American Society for Testing and Materials D8 and E6 committees.

Round-robin testing to measure the coefficient of linear thermal expansion of roofing membranes has begun. A test method was developed to measure the water vapor permeability of roofing membranes; laboratory tests are in progress.

EVALUATION OF ELASTOMERIC ROOFING

Walter Rossiter
Structures, Materials and Safety Division - 3401-921-3407

Sponsor - Tri-Services Committee

Elastomeric roofing materials are being used in greater quantities because of economic considerations, shortages of conventional materials and the special requirements of roofs such as domes, barrels, and hyperbolic paraboloids. While the performance of elastomeric roofing may be as good as or better than conventional systems, there are essentially no criteria against which to measure the per-

formance of this type of roofing systems.

In this project, the performance of elastomeric roofing materials and systems is being investigated by field observations, discussions with material producers and a review of literature. The information obtained will be related to actual in-service performance such as tensile strength, extensibility, adhesion to various substrates, strength of bonded joints, abrasion resistance, and effects of temperature variation and weathering. Data and information obtained from the field, literature studies, and consultations with materials producers will be used in the development of design, material, and construction guidelines and preliminary performance criteria.

VISCOSITY GRADING CRITERIA FOR ROOFING ASPHALT

Walter Rossiter
Structures, Materials and Safety Division - 301-921-3407

Sponsor - Tri-Services Committee

In this project, the viscosities of roofing asphalts now in use were measured at temperatures covering the range normally used in roofing construction. Twenty roofing asphalts from various crude oil sources were collected. The kinematic viscosities of the asphalts were measured at 166 °C (330 °F), 193 ° C (380 °F), and 221 °C (430 °F).

In addition, 48 three ply built-up membranes were field constructed at known temperatures within the range 163 °C (325 °F) to 260 °C (500 °F). The thickness of interply asphalt in each sample was measured. The relationship between viscosity and interply thickness will be discussed in the final report and a viscosity grading criterion will be proposed. The report, for which all data are now on hand, will be prepared as part of the "Performance of Roofing" project.

FIELD SURVEY OF ROOFING

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

Sponsor - Department of the Army

This project is to complete a report on the field survey of roofing at military installations for which on-site roof inspections were made in previous years. The report will cover the condition of the roofs which were inspected, and make recommendations for improvement of design, material and application specifications for roofing. Consultation will be provided to the U.S. Army, at their request, for the purpose of solving roofing problems. The consultation will include field inspections of roofs and laboratory tests as needed to provide recommendations for proper repair, replacement, and/or selection of roofing systems.

FIBER-REINFORCED CONCRETES AND MORTARS

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

Sponsor - National Bureau of Standards

Fiber-reinforced polymer-impregnated mortars and concretes are new types of building materials that have great promise. Because of their anticipated strength and toughness, it should be possible to use them in prefabricated roof and wall elements and other structural components of single-family dwellings and larger buildings. However, per-

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formance criteria must be established before these materials can be widely used in building construction. This project will contribute to the knowledge required to establish performance criteria.

The flexural and compressive strengths of control mortars, fiber-reinforced mortars, and polymer-impregnated, fiber-reinforced mortars have been measured and the corresponding load-deformation curves recorded. The fibers used have included chopped steel and glass rovings. In the case of chopped steel, the fiber variables have been length, cross-sectional shape, and tensile strength. At given volume concentrations of fibers, the results have shown marked differences in behavior attributable to differences in fiber-matrix bond strength, fiber tensile strength, and fiber length. The importance of fiber tensile strength has been apparent in polymer-impregnated specimens where the bond strengths have been sufficiently high to prevent fiber pull-out from the matrix during fracture. The project is being completed with measurements of the bond between the matrix and individual fibers.

NONDESTRUCTIVE EVALUATION OF BUILDING MATERIALS

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

Sponsor - National Bureau of Standards

Because concrete is one of the nation's most important structural materials, there is a need for reliable techniques for inspection of concrete at all ages, both to expedite construction and to protect the public. The present range of techniques for inspection of concrete is inadequate to meet the needs of inspectors, which are growing with the increasingly critical demands made upon concrete in high-rise buildings and nuclear power plants. There is a need for critical evaluation of the existing techniques and for the development of performance standards for new techniques.

The literature and other sources of information on nondestructive evaluation (NDE) of concrete have been critically reviewed. Individuals, research institutes, and standards organizations will be contacted. The adequacy of current information on the available methods will be assessed and research needs related to the NDE of concrete identified.

CORROSION OF METALS

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

Sponsor - National Bureau of Standards

Metals and alloys are important constituents of almost all structures (e.g., pipe, electrical wiring, reinforcing bars, steel beams, roofing, siding, etc). However, the corrosion of metals and alloys is a major problem and the estimated annual loss attributed to corrosion amounts to several billions of dollars.

In this project, the protective properties of organic and metallic coatings on metallic substrates are being assessed. Technical methods are being used to measure rates of corrosion, the nature of the interface between the substrate

and coating, and cohesion and adhesion of the coating. Existing methods are being evaluated and new methods developed to determine the corrosion state of coated and uncoated metals and to measure the rate of corrosion. Ways to reduce the corrosion of metallic piping are also being evaluated.

In FY75, data were obtained on the protection against corrosion provided by zinc coatings (galvanizing) on steel rebars and of epoxy coatings on rebars embedded in concrete prisms. The specimens were exposed to different concentrations of chloride and, for the galvanized bars, the effects on the corrosion rate of small holes of various known sizes cut through the zinc coating were investigated. Preparations have been made for a study of the weathering of thirteen metal siding and roofing materials with a range of metallic coatings. Electrochemical test equipment, needed for more detailed studies of corrosion, has been obtained.

In FY76, the Center is completing the studies of the protective properties of zinc on steel rebars. Test specimens of metal sidings and roofing panels will be placed at exposure sites. An investigation of the corrosion of hot water pipes has begun. The corrosion of steel-fiber reinforced mortars immersed in aqueous solutions containing chloride ions will also be studied.

CORROSION OF PIPES AT MILITARY FACILITIES

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

Sponsor - Tri-Services Committee

The corrosion of piping used for the transportation of hot water and steam at military installations costs millions of dollars per year from maintenance and replacement and in interruption of services. This is part of the more than 8 billion dollars per year cost of corrosion in the United States. The full extent of the problems has not yet been identified since they are usually dealt with on a local basis.

Major corrosion problems associated with piping at military facilities have been identified by review of corrosion survey reports and discussions with representatives of the Tri-Services Committee on Materials. A final report has been prepared in which these corrosion problems are discussed and recommended practices to minimize the corrosion of piping are given.

GUIDELINES FOR EVALUATION AND USE OF UREA-FORMALDEHYDE FOAMED RESIN AS A THERMAL AND SOUND INSULATION

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

Sponsor - Department of Housing and Urban Development

The energy crisis has increased interest in the use of foamed polymeric insulations because of their improved insulation characteristics and their ability to be used on irregularly shaped surfaces or in spaces where access is difficult. There have been problems associated with such foams used in residential construction. However, many of these problems can be resolved by proper design, selection of areas of application, formulating, and proper application.

The Center for Building Technology (CBT) will identify the properties of urea-formaldehyde foam that affect its performance as thermal and sound insulation, and evaluate existing test methods to measure these properties. Test methods such as air sampling and analysis after installation are to be identified and examined. CBT will prepare guidelines for the evaluation and use of foam insulation that will include recommended levels of performance of this material. The guidelines will also include suggested formulations of the urea-formaldehyde foam, application methods, curing techniques, and areas of application.

POLYURETHANE SEAMLESS FLOORING

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

Sponsor - Department of Housing and Urban Development

The use of a durable flooring system in the high traffic areas of public housing offers great potential savings. A new water-thinned polyurethane flooring system is claimed to be a durable high performance system, easily cleaned, and easily applied and resurfaced. Also, the hazards of toxic solvents and monomer are eliminated. The simplicity and reduced hazard of the system offer potential advantages for application in tenant self-help programs. However, because the system is new, its performance characteristics need to be determined.

In this project, both laboratory testing and field demonstrations provide the basis for evaluation and for recommendation of a performance specification. Laboratory testing has included abrasion resistance, accelerated aging, and comparison of the performance with that of other flooring systems. Field demonstration tests are being coordinated by the Center personnel.

In FY75, substrates were obtained and prepared for application of the system. A format was devised for monitoring the application and performance in each of the 10 Department of Housing and Urban Development regions. The application of the system at the selected sites was carried out and the performance is now being monitored.

RESTORATION AND PRESERVATION OF ADOBE MATERIALS

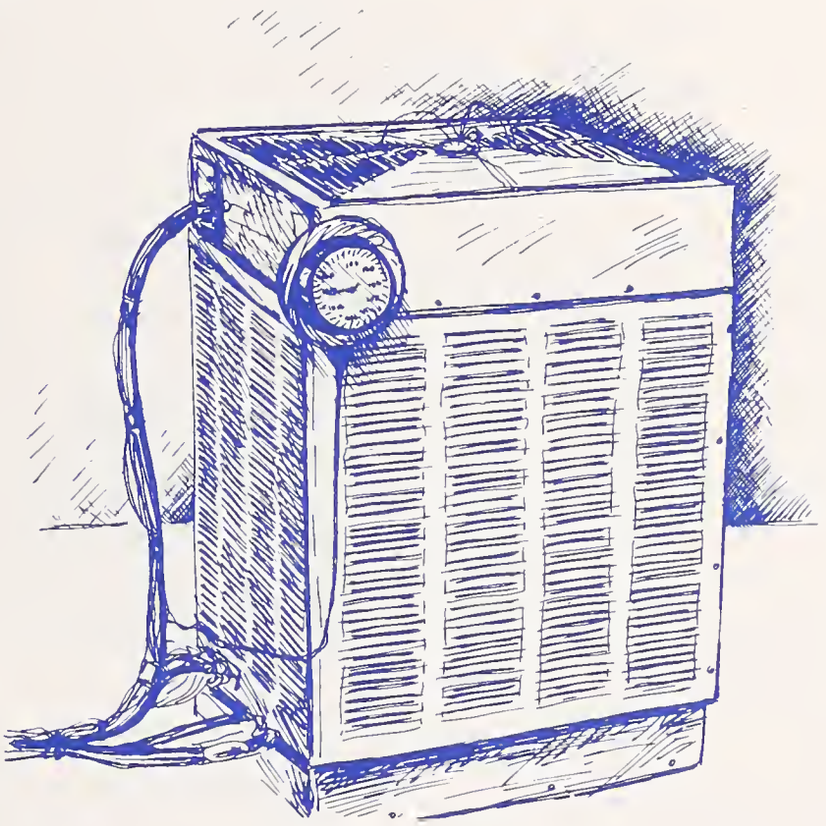
James Clifton
Structures, Materials and Safety Division - 301-921-3407

Sponsor - National Park Service

The National Park Service (NPS) has responsibility for the preservation of many historic adobe structures. In deciding on the appropriate preservation action for any adobe structure, NPS needs information on the composition and physical properties of adobes, the responses of adobes to environment exposures, and methods for stabilizing adobe structures.

In this project, the adequacy of current information on the properties of adobe is being determined and research needs related to the preservation of adobe are being identified. This analysis will lead to a research program to characterize the important properties of adobe.

Mechanical Systems



PART-LOAD HEATING, VENTILATING, AND AIR-CONDITIONING EQUIPMENT

George Kelly
Building Environment Division - 301-921-3521

Sponsor - National Bureau of Standards

With this project, the Center for Building Technology (CBT) is developing test methods in support of consensus standards for part-load testing and rating of unitary heat pumps, air-conditioners, and heat plants for residences and small buildings.

At present, the heating, ventilating, and air-conditioning industry equipment performance ratings are based on steady-state test methods. This has led to a continuing dispute on the actual field performance of heating/cooling equipment. 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 heating, ventilating, and air-conditioning systems.

During FY75, test rigs were constructed for boilers and air-to-air heat pumps, and now data are being obtained. A paper was published on gas-fired boilers and another is being prepared on heat pumps. Part-load operation was shown to have a very detrimental effect on the performance of gas-fired boilers and heat pumps operated in the cooling mode. The performance of heat pumps providing heating was found to be most affected by ice-build-up on the outdoor coil and defrosting, although operation at part-load in the non-frosting region also tended to lower the heat pump's performance.

During FY76, CBT continued collecting data on gas-fired boilers and air-to-air heat pumps. Theoretical models of fossil fuel heating plants and heat pumps are being studied. Contacts are being made with industry and the appropriate standards-writing organizations concerning a joint effort at developing a better performance standard for gas-fired boilers and heat pumps. Work has started on documenting the effect of part-load operation on other heating, ventilating and air-conditioning equipment, such as oil-fired furnaces and boilers, gas-fired furnaces, and chillers.

HEAT PUMPS

George Kelly
Building Environment Division - 301-921-3521

Sponsors - National Bureau of Standards;
Federal Energy Administration

The study will determine the part-load and seasonal performance of electrical heat pumps by testing one electric motor-driven heat pump in the field and another in the laboratory. The Center also will evaluate the potential for using engines to drive heat pumps.

Data were collected during the summer of 1974 and the winter of 1974-75 on the dynamic performance of the heat pump during tests to determine the cooling and heating requirements of a test house. These data seem to indicate that considerable energy savings may be possible. The Center, through monitoring activities, documented the performance of the test house heat pump during the 75-76 heat-

ing season. An electric motor-dirven heat pump and an engine-driven heat pump will be studied in the laboratory under carefully controlled conditions. This will allow for a much more rigorous evaluation than is possible under field conditions.

OIL HEAT UTILIZATION

George Kelly
Building Environment Division - 301-921-3521

Sponsor - Federal Energy Administration

This project will identify areas of research and development in the oil heating field which have the best potential for improving the utilization of fuel oil. It will rank these areas according to how rapidly they contribute to energy conservation (immediate, short term, long term, etc.), estimate the chance of successfully completing a research and development program in each area, and determine the amount of funding needed for these programs.

A technical panel consisting of personnel from the National Bureau of Standards (NBS), National Oil Fuel Institute, the oil industry, universities, and a fuel oil dealership will conduct the research. NBS personnel will evaluate proposed research projects in the most promising areas. In carrying out this evaluation, the advice of various panel members and experts in the field will be solicited.

A TECHNICAL CONFERENCE ON THE IMPROVEMENT OF HEATING, VENTILATING, AND AIR-CONDITIONING EQUIPMENT

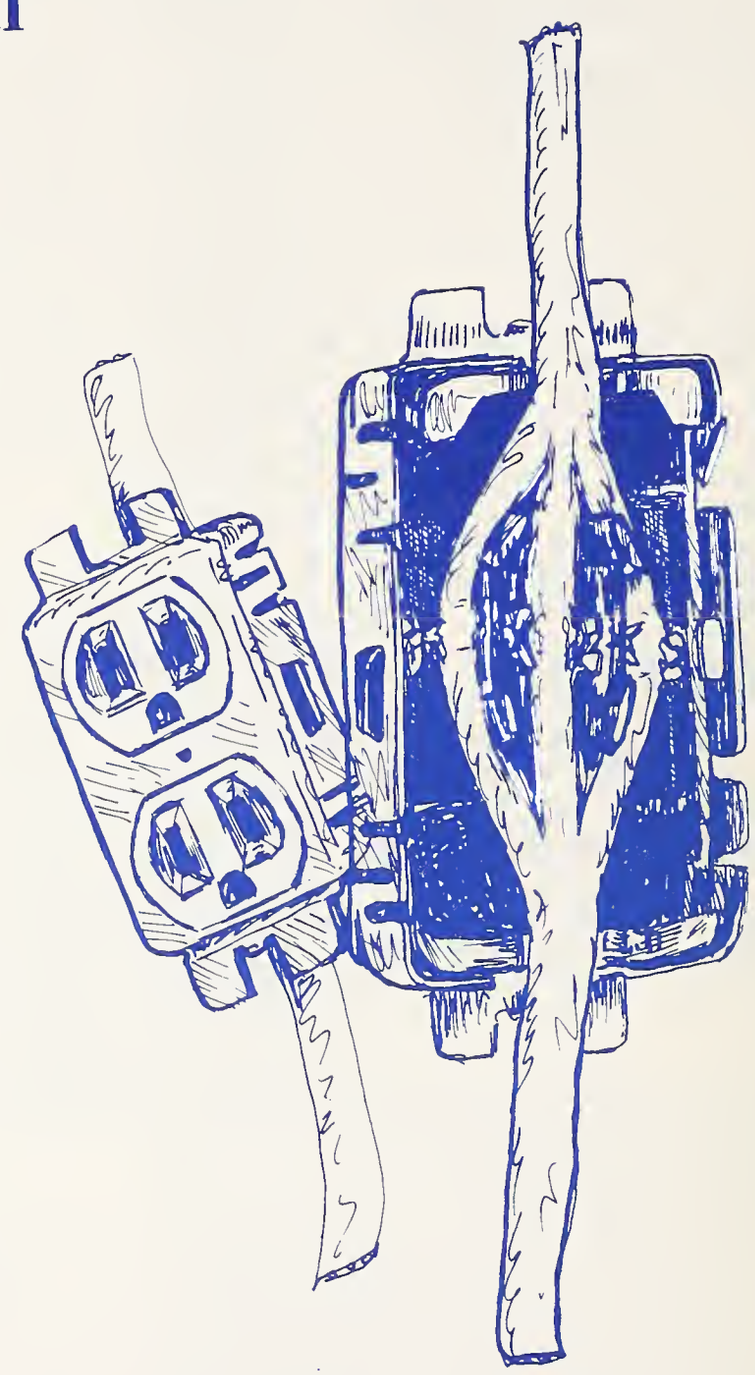
David Didion
Building Environment Division - 301-921-2994

Sponsor - Federal Energy Administration

The project organized and presented a technical conference jointly managed by the National Bureau of Standards and Purdue University. The goals of the conference were to exchange and document concepts and applications that can lead to a reduction, and understanding, of the energy used in air-conditioning and heating in commercial and industrial buildings. The objectives also were to provide leadership and stimulation in equipment and system design, analysis of system performance, and energy conservation potentials.

Papers that deal with current practices leading to a minimization of energy consumption were included. The sessions were primarily intended for engineers responsible for component design and manufacture, system design and selection, and building operation.

Electrical



INNOVATIVE ELECTRICAL CONNECTIONS

William Meese
Building Environment Division - 301-921-3293

Sponsor - Department of Housing and Urban Development

Fire safety, long life requirements, codes and other institutional constraints, and a lack of technical data based on performance, have led to slowly changing regulations concerning electrical connections in residential branch circuits. Innovations involving electrical connections could lead to significant advancements and lower costs in housing construction if safety and functional requirements could be satisfied. Laboratory investigations are needed to determine failure mechanisms of electrical connections so that meaningful performance criteria and test methods can be established.

The approach to: (1) obtain and analyze current technology, including code and other institutional constraints, (2) develop preliminary performance criteria and test methods and identify research needs, (3) determine how electrical connections fail under simulated "real world" conditions, (4) develop technical data needed in the evaluation of electrical connections, and (5) develop and publish criteria and test methods for the evaluation of innovative electrical connections.

FY76 plans are to continue to develop data involving overheating failure mechanisms and to continue to develop other technical data, including an improved method to measure connection quality. Development of criteria and test methods will be undertaken and testing in accordance with the criteria will be performed. Unexpected tentative results indicate that innovative connectors developed and under development by industry appear to not only provide significant cost savings, but also provide superior characteristics relative to physical and durability requirements.

INNOVATIVE ELECTRIC WIRING SYSTEMS

William Meese
Building Environment Division - 301-921-3293

Sponsor - Department of Housing and Urban Development

In this project, performance standards and test methods for non-metallic sheathed electrical residential branch-circuit wiring are being developed. Extensive new restrictions have been placed on the use of such cable (romex) by the 1975 National Electric Code. The lack of appropriate technical data on which to base these restrictions and the resultant increase in the costs of housing have illustrated the need for objective research. Flat conductor cable, which has been extensively used for aerospace purposes, promises to bring economies to residential branch circuits if appropriate National Electrical Code "expectations" can be satisfied.

The approach to this project is to (1) obtain and analyze bases for the National Electrical Code restrictions on non-metallic sheathed cable and obtain and analyze any applicable technical data and institutional restraints on conventional and innovative branch-circuit electrical systems; (2) develop and perform laboratory and field investigations to obtain data for the evaluation of such electrical systems,

including data on failure mechanisms; (3) develop and publish criteria and test methods for the evaluation of conventional and innovative electrical branch circuit wiring systems.

Last year, a preliminary study of flat conductor cable for residential wiring systems, including information on a prototype installation in Yonkers, New York, was made.

This year, the Center is determining areas where data are needed. Literature reviews and laboratory investigations in areas where it is known that technical data are needed (such as cause, spread, and effects of fires in branch circuits) will simultaneously proceed.

ELECTRICAL SERVICE QUALITY MEASUREMENT

Adolfo Camacho
Building Environment Division - 301-921-3293

Sponsor - National Bureau of Standards

Quality of electrical service affects the operation and durability of electrical and electronic appliances and other equipment. Representative data on variation from standard electrical service characteristics are needed to establish elements of design requirements for electrical and electronic equipment in buildings. The lifetime of equipment may be improved by development of improved control and better regulated supply at the building service entrance.

A spinoff of the National Aeronautics and Space Administration's spacecraft flat-conductor wiring to building electrical circuit service is sponsored by the Technology Transfer Office. Economical installations are potentially great, particularly in retrofits.

Instrumentation was rented and preliminary field measurements were made. Even though enough measurements have not been taken to be statistically valid, the number of low-voltage transient events indicate a need for in-depth studies. It has been determined that some low-voltage events are caused by the irregular demands of electrical equipment in the building. Also, a flat conductor report was completed on a field installation in Yonkers, New York.

ALUMINUM WIRING IN BRANCH CIRCUITS

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

Sponsor - Tri-Services Committee

Aluminum wiring in branch-circuit electrical systems of homes and other buildings on military bases has been increasing since the mid 1960's. Recently, overheated receptacles and switches have been reported in many buildings. There is concern that overheated devices could present a fire hazard. Studies of aluminum wiring on military bases are needed to identify mechanisms by which overheating might occur, and to develop recommendations to ensure the connections to aluminum will not overheat.

In this project, military bases having aluminum electrical wiring are being identified and the wiring at selected bases is being inspected. Information obtained from the inspections will be used to hypothesize failure mechanisms and to design laboratory experiments to verify the mechanisms.

RADIANT HEATING IN SEAMLESS FLOORING

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

Sponsor - Department of Housing and Urban Development

Public housing usually has a disproportionate share of elderly and very young residents. Adequate, well-designed, and economical heating systems have a direct bearing on their health and comfort. A novel approach to heating is to provide radiant heat by electrical resistance heaters embedded in, or beneath, seamless floors.

This study will include a literature survey on the feasibility of the radiant-panel seamless flooring system, preparation of a small-scale laboratory heating system, evaluation of the system, identification of the heating components and flooring systems for use in a radiant heating system, and recommendations for future research, such as human response factors or life-cycle costing.

Literature on both radiant heating elements and seamless flooring systems has been reviewed. Nineteen flooring systems have been obtained and performance testing of the systems has been carried out.

ENERGY USAGE OF HOUSEHOLD APPLIANCES

Richard Grot
Building Environment Division - 301-921-3293

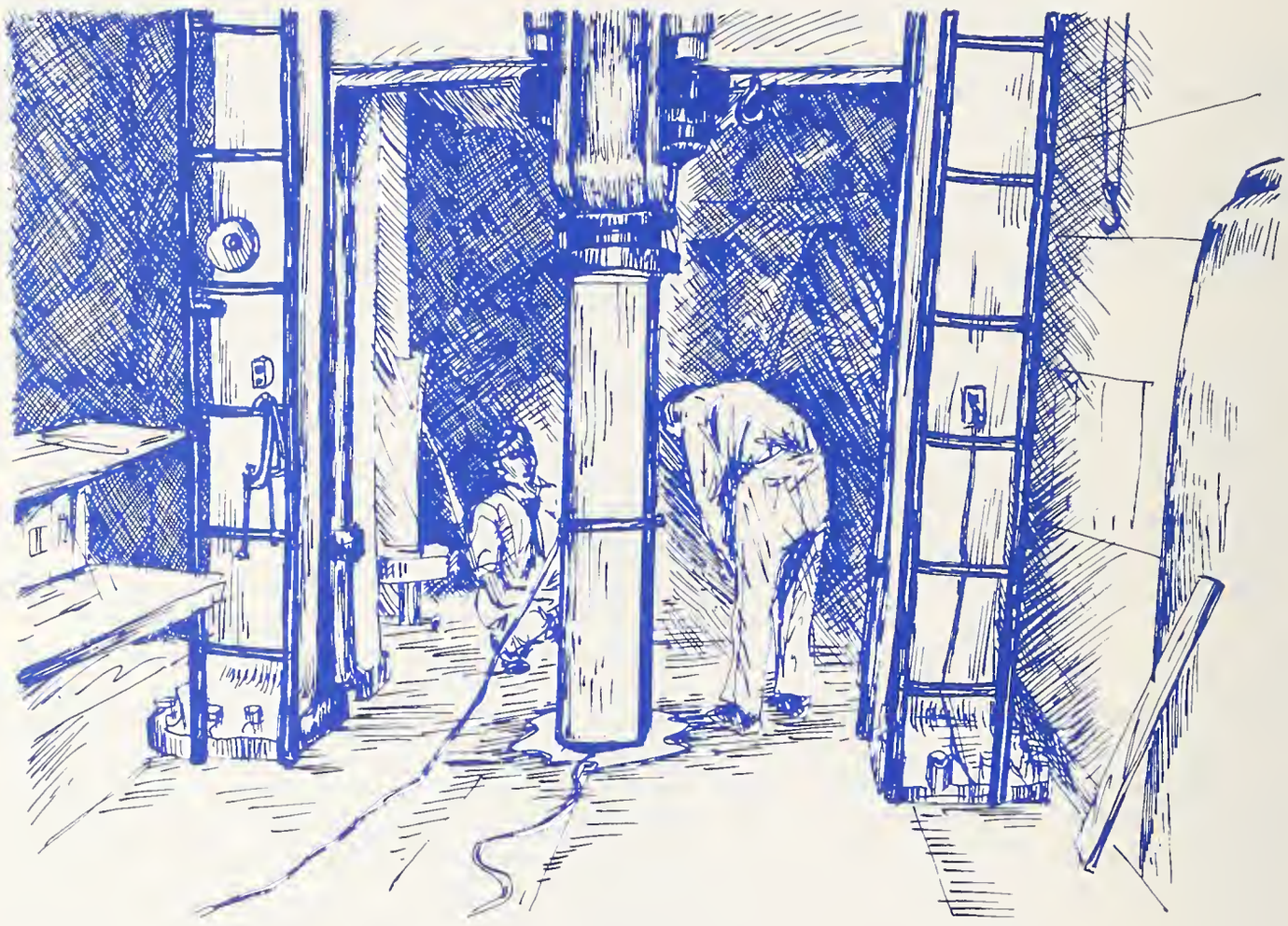
Sponsor - National Bureau of Standards

As directed by Congress, the Consumer Product Safety Commission has the responsibility for a program of energy labeling for major household appliances. The effectiveness of this labeling depends on the establishment of realistic test procedures for determining efficiency At present, there are insufficient data on actual usage of household appliances to determine if the proposed test methods reflect the actual operational characteristics.

In this project, the instrumentation, data analysis, schemes, and field methods developed in the other Center projects "Measurement Technology" and "Utility Load Measurement" are being used to determine the energy performance of household appliances. Instrumentation packages for monitoring appliance usage in a sample of dwellings are being assembled and deployed.

Two instrumentation packages for monitoring the energy usage patterns of household appliances have been assembled and are being installed in residences at Twin Rivers, New Jersey. Data have been gathered on the usage of energy in a single residence in order to check the instrumentation scheme and provide preliminary data. The instrumentation developed during FY75 is being used to monitor the energy usage of household appliances in eight residences at Twin Rivers (four of which have electric appliances, four of which have gas appliances). Representative periods of usage will be chosen for each season of the year.

Structural



WIND LOADS ON STRUCTURES

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

Sponsor - National Bureau of Standards

The purpose of this project is to improve building code provisions regarding wind effects on buildings and other structures. Recent trends in design philosophy, use of new materials, and innovative construction details have led to structures with an increased sensitivity to wind effects. As Secretariat of the American National Standards Institute, Inc. Committee A58.1, the Center has a vital interest in the development of suitable criteria to ensure the design of buildings that will perform satisfactorily under wind conditions likely to occur during the anticipated life of the structure.

The project involves the use of experimental data currently available and the collection of additional data, either by the use of wind tunnel modeling or by direct measurement of structures in service. Along with this, theoretical models will be developed and checked against experimental results. Among other outputs of this project are: publication of a report *The Buffeting of Tall Structures by Strong Winds;* publication of *Equivalent Static Wind Loads for Tall Building Design,* 4th World Conference on Wind Effects on Buildings, September, 1975; publication of *Probabalistic Models of Extreme Wind Speeds: Uncertainties and Limitations,* 4th World Conference on Wind Effects on Buildings, September 1975; publication of *Engineering Aspects of Cyclone Tracy,* National Academy of Engineering Report; and publication of *Wind Pressure on Single-Family Dwellings.*

HIGH WIND STUDY FOR DEVELOPING COUNTRIES

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

Sponsor - Agency for International Development

The research addresses developing improved design criteria for low-cost/low-rise buildings to better resist extreme winds. Existing criteria for wind loads do not adequately provide for steady and fluctuating wind pressures along the edges of roofs and walls where separated flows occur. Extreme suction pressures in these regions are one of the primary contributors to building damage. Thus, such research can result in substantial benefits both in the U.S. and in other high-wind areas.

This project analyzes wind loadings on a sample of six low-rise buildings at three statistically independent test sites in the Philippines. Wind tunnel modeling of the six test buildings is being performed, with the appropriate correlation analysis. Climatological, social and housing information also are being analyzed.

The following activities were completed in FY75: (1) instrumented the remaining two of the six Philippine test houses; (2) validated wind-tunnel modeling techniques to simulate natural surface winds with representative measurements obtained from full-scale buildings; (3) analyzed wind and pressure data on the six full-scale test buildings; (4) developed extreme wind distributions for the Philippines; (5) monitored the progress of the Bureau-trained Filipino

technicians; (6) conducted a wind tunnel model study of a Republic of Philippine-United States school building and prepared reports on test results.

The FY76 plans are for the following: (1) continuation of full-scale test program at the three field-test sites through December of 1975 (end of typhoon season); (2) reduction and analysis of full-scale data; (3) limited investigation of wind tunnel models to aid in the interpretation and extension of full-scale test results; (4) incorporation of field data and subsequent laboratory test data as a result of damage to Darwin, Australia, due to Cyclone Tracy; (5) refinement of wind load criteria; and (6) regional seminar in Kingston, Jamaica, November 1975.

Last year, a 15-minute color-sound film was produced on the effect of winds on structures; it has been shown to a number of international audiences. Also, consumer-oriented versions of all the reports prepared for this project will be published for world-wide distribution.

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

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

Sponsor - National Bureau of Standards

The existence of the standard, Building Code Requirements for Minimum Design Loads in Buildings and Other Structures, over the past fifty years has demonstrated the need for a consistent nation-wide standard for loads on building structures. The use of this standard has to be further encouraged because the model building codes are not consistent with respect to loadings on building structures.

It is obvious that a consistent set of design loads should be used and that a particular structure in a particular geographical location should have the same load on it regardless of which code is applied. This is not the case now. 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 steel and concrete structures.

As a result, this project is to support the administrative operations of the Secretariat of the American National Standards Institute, Inc. (ANSI) Committee A58, Building Code Requirements for Minimum Design Loads in Buildings and Other Structures. This Secretariat also includes the USA Technical Advisory Group Administration for the International Organization for Standards 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, A58.1-1972.

STRUCTURAL RELIABILITY

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

Sponsor - National Bureau of Standards

There is a growing interest on the part of the engineering profession in the use of probabilistic methods in developing design criteria. The central role played by the Center in standards development necessitates a program in structural reliability.

The purpose of this project is to develop a methodology to facilitate and systematize the selection of design criteria. The procedures will explicitly reflect design uncertainties, risks, and consequences of failure, and provide an improved basis for evaluating design alternatives with regard to strength and serviceability. The concepts will be demonstrated with a case study employing realistic data on loads and properties of materials.

PERFORMANCE STANDARD: FOUNDATIONS AND EXCAVATIONS

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

Sponsors - National Bureau of Standards; Department of Housing and Urban Development

The American National Standards Institute, Inc. Standard A56, for foundations and excavations, will be replaced by a performance standard prepared under an American Society of Civil Engineers (ASCE) standards committee. The standard will be prepared under the direction of the recently appointed ASCE Committee of Foundations and Excavations. The technical work necessary to prepare a draft standard is funded by the Department of Housing and Urban Development (HUD). The funds under this project will be used for administrative support associated with the ASCE Committee work. This committee support will continue beyond the duration of the HUD project, until all balloting is complete and the standard is ready for publication, and probably beyond this time for the review of feedback from the application of the standard.

GEOTECHNICAL ENGINEERING

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

Sponsor - National Bureau of Standards

The annual loss in the U.S. by foundation distress and soil stability failure is estimated to exceed $3 billion. As a result of the energy crisis, subsurface exploration will be conducted on a large scale and the construction of mass transportation systems will be stepped up in many metropolitan areas. There will also be a significant increase in strip mining and deep mining, sometimes adjacent to, or under, settled areas. Subsurface exploration requires new and more sophisticated measurement techniques. Mass transportation projects involve excavation, dewatering and pile driving, thus endangering adjacent buildings and activities. Deep mining causes subsidence and strip mining creates slope stability and re-grading problems. All these problems are within the geotechnical domain.

This project will look at the overall problems, the role of various other Federal agencies in this field, and the national needs, to determine the proper role of the National Bureau of Standards (NBS). This effort will provide much needed direction and insure that the overall

NBS program in the geotechnical area is consistent with the NBS mission and adequately responds to national needs.

In addition to developing an overall research program in geotechnical engineering, a more specific study is underway: the measurement of the effect of excavations on adjacent structures and *in situ* measurement of soil properties.

RESIDENTIAL STRUCTURES IN MINING AREAS

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

Sponsor - Department of Housing and Urban Development

As a result of the energy crisis, increasing land will be subjected to underground and strip mining. In spite of the environmental degradation in these areas, rising land values will create increasing pressure to use the land for residences. The resulting problems are subsidence and collapse of supporting soil, erosion, disrupted drainage patterns, contamination of surface waters, and slope stability. There is a need to investigate these problems to provide adequate guidance for future Department of Housing and Urban Development (HUD) policies.

This project will assemble information on the extent of residential areas affected by subsidence problems in the U.S., and assess the probable dimensions of the problem in the future. Localities now affected will be visited to gain an understanding of the need for design provision and code regulation, and to study the technical details of the problems which were conducted in Wilkes Barre, Pa. The Center proposal will be prepared for HUD for the preparation of performance and design criteria, practice standards, and perhaps a catalogue of acceptable design solutions.

In FY75, a field examination of mine subsidence problems was conducted in Wilkes-Barre, Pa. The Center conducted detailed review with HUD and their consultants to define areas of priority.

SHEAR TRANSFER PHENOMENON IN REINFORCED CONCRETE

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

Sponsor - Nuclear Regulatory Commission

Current design assumptions rely very little on the resistance of the concrete or the resistance contributed by the interaction of the concrete and the reinforcing steel. This research project will study the possible improvement of design methods by evaluating the applicability of the interface shear transfer mechanism for the design of the containment building. Research data obtained on the shear transfer mechanism are also applicable to other building types constructed of reinforced concrete.

The containment building of a nuclear reactor for 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. Improvement of 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 the reinforced concrete containment building of nuclear power plants but also to the walls, beams, footings and pile caps in other types of building structures.

DESIGN CRITERIA FOR MASONRY

Felix Yokel
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Sponsors - National Bureau of Standards; Tri-Services Committee; Brick Institute of America

A cooperative program of research between industry and government has been established by the Center to improve the design of masonry structures in seismic regions. This project responds to the need for more information on the response of masonry structures to earthquake loads, to develop design criteria similar to those now used for steel and concrete construction.

This project has three phases. Phase I: A study to compare existing standards, codes, and informal design practices with the state of the art, to compile test information, and to identify information that will require additional research. Phase II: A test program, designed to develop information on strength, stiffness, and ductility of shearwalls, to develop tests capable of measuring these properties, and to evaluate the performance of various design details. Phase III: The synthesis of results and development of design criteria.

REQUIREMENTS FOR MASONRY, AMERICAN NATIONAL STANDARDS INSTITUTE STANDARD A41

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Sponsor - National Bureau of Standards

Compared with those of other construction materials, design standards for masonry are lagging. Because of industry fragmentation, there is also no overall consistent approach to masonry design, encompassing brick, concrete, block, composite construction, and other types of masonry. Besides the need for design standards for "engineered masonry," it is also necessary to preserve and revise the present empirical standard, since the majority of masonry construction consists of projects for which the masonry is not designed by professional engineers. Damage to masonry construction recently observed in the Washington, D.C. area after a rather moderate storm underscores this need.

Under this project, an empirical standard will be pre-

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pared under the American National Standards Institute, Inc. Standard A41.1. Beginning with the work accomplished in FY75, a draft document was prepared by the Center's staff and put before the drafting committee for approval. This draft will then be reviewed and put out for ballot to the A41 Committee.

MODEL STUDY OF A PARKING GARAGE COLLAPSE

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Sponsor - National Bureau of Standards

Unbonded post-tensioned concrete is a relatively new type of construction that is being widely used because of economy. However, because of its newness, there is not a wide technical base for current design and construction standards. Thus, the recent catastrophic collapse in Fairfax County, Va. of a parking garage using this type of construction has raised a fundamental question within the engineering design profession, "Did the garage collapse occur simply because the structure was overloaded, or did the collapse occur because of some unknown weakness in design standards governing unbonded post-tensioned construction?" The answer to this question can have a significant impact on codes and standards.

An experimental investigation is being conducted using direct structural model testing. The direct structural model is essentially a true-to-scale analogue computer for the direct solution of an actual structural system. This type of model emphasizes agreement between prototype and model physical characteristics and boundary conditions. The model may be used to document elastic, inelastic, and ultimate load behavior.

In FY75, a "calibration" model SS-1, consisting of an isolated column with a surrounding slab sector and a "strip" model, SS-2, consisting of a one-panel by four-panel section were fabricated and tested to failure. Data reduction for the two models was started. Fabrication of a "segment" model, SS-3, tentatively consisting of a four-panel by four-panel section,was begun.

For FY76, data reduction for models SS-1 and SS-2 will be completed prior to a decision on the actual size of the segment model. Analysis of the data will dictate the actual size of model SS-3. Model SS-3 will be tested under various elastic and inelastic loading conditions. The model will be tested to destruction under a selected loading case.

AIR FORCE MOBILE SHELTERS

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

Sponsor - Department of the Air Force

The acceptance of Air Force mobile shelters is based on the results of structural tests that are believed to simulate the transportation and operational loads that the shelters experience during their service lives. This procedure can lead to shelters that are over-designed with respect to certain service loads and is costly when the shelter fails to pass some of the required tests.

In this project, a study will be made to identify and estimate the probable loads shelters will experience. Structural models will be developed to represent the basic shelter types and shelter responses to probable loads. Instrumentation to measure and record shelter responses in actual load tests will be recommended and a field-test program will be outlined to provide shelter responses for comparison with the analytical results.

Codes and Standards

BUILDING STANDARDS, IMPROVEMENT AND IMPLEMENTATION

James Pielert
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Sponsor - National Bureau of Standards

This multifaceted project involves the interaction of the Bureau with the building regulatory sector, the model code writing organizations, the building standards generating groups and the building community as a whole. This will be facilitated by the establishment of an Institute for Applied Technology (IAT) Building Standards Council for identifying priority standards requiring the Center's expertise and for developing input for these standards organizations. This effort will coordinate the Center's mobile home research activities to speed the transfer of results to users through the standards generating process. Additionally, future support will be provided to the National Institute of Building Science.

During FY75, the Standards Council identified four high priority Standards; American National Standards Institute, Inc. (ANSI) Committees A40, A56, A58, and A119. The concept of the Center providing administration assistance was adopted by the Standards Council. *ANSI A119.1 - Mobile Homes and Recreational Vehicles:* the Center actively participated in the development of ANSI A119.1-1975 which was adopted by ANSI in February 1975. Coordination of the Center for Building Technology mobile home activities continued and a Federal Mobile Home Workshop was held in March 1975. *ANSI A40 - Minimum Requirements/ Plumbing:* the Bureau has strongly encouraged the updating of the National Plumbing Code. Input to the committee was provided by presentations at three meetings by the Center's staff mmbers. A complementary activity based on the Center's presentations is the development of a plumbing performance standard.

During FY76, the IAT Building Standards Council became operational with maintenance support provided for high priority standards. These include ANSI A40, A41, A58, A119, Foundations and Excavations, the American Society for Heating, Refrigerating and Air-Conditioning Engineers 90-75 and Solar Standards. The Center also will, among other activities, publish and maintain a listing of all standards referenced in State and model building-related codes and the codes of 30 largest U.S. cities, identifying the current standard and those sections in the codes where they are referenced. This project will be coordinated with the Standards Information Services Section of IAT. This list will be annually appended and updated, then printed and distributed to the National Conference of States on Building Codes and Standards, the Council of American Building Officials, and the Association of Major City Building Officials. Likewise, a complete building code file containing copies of each of the building-related codes adopted as statewide codes, those codes published by the model code organizations, and those codes adopted by the 30 largest cities in the U.S. will be established and maintained. This file, probably the only one of its type and completeness, will provide a ready reference source for other Bureau activities.

NATIONAL CONFERENCE OF STATES ON BUILDING CODES AND STANDARDS

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

LABORATORY EVALUATION AND ACCREDITATION PROGRAM

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Sponsor - National Bureau of Standards

As requested by the National Conference of States on Building Codes and Standards (NCSBCS), a Laboratory Evaluation and Accreditation Program (LEAP) was established to develop criteria and a methodology to determine the capabilities of laboratories and agencies to perform the engineering analysis, testing, and inspection required by building regulatory authorities. The LEAP project developed specific criteria and methodology documents for such agencies to perform regulatory functions dealing with the construction of manufactured buildings. These documents have been reviewed by NCSBCS and have been processed by the American Society for Testing and Materials as national consensus standards. Pilot projects with individual States and with NCSBCS were underway to demonstrate the procedural mechanisms for laboratory evaluation and accreditation based on the LEAP concepts.

COORDINATED EVALUATION SYSTEM

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Sponsor - National Bureau of Standards

The operational concept of the Coordinated Evaluation System (CES) has been adopted in several State agencies involved in the regulation of mobile homes and manufactured buildings. Independent third-party evaluation agencies and manufactured building producers have also incorporated CES-developed model documents into their activities relating to institutional evaluation and regulatory compliance functions. Computer-based-information systems to summarize and report on the status of State building regulatory programs for mobile homes, manufactured buildings, and preemptive building codes and

standards for conventional construction have been developed in conjunction with on-going data collection activities. A study to determine the extent which the American National Standards Institute, Inc. (ANSI) Mobile Home Construction Standard, ANSI A119.1, has been modified by individual State amendments, was completed.

In FY75, the information on mobile homes and manufactured building regulatory programs adopted by the States was significantly expanded and resulted in the publication of two summary reports. A national survey on the adoption of statewide building codes and building speciality codes has provided the first reliable data on the number, type, degree of preemption, and coverage of State building regulatory programs, and the specific codes and standards used. The CES final report on model documents for the regulation of manufactured buildings completes this aspect of project activity.

In FY76, this work was extended by a report on the adoption of statewide building codes for conventional construction. The project will also report on the status and extent to which individual States have adopted and/or modified codes and standards dealing with the construction of manufactured housing. The Center is developing a methodology to study the impact of statewide building codes on costs and performance, inconsistent code provisions on costs and performance, and the extent of overlapping regulatory jurisdictions and their impact on performance.

COORDINATED METRIC DIMENSIONS FOR BUILDINGS

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Sponsor - National Bureau of Standards

The Center for Building Technology (CBT) will provide leadership to the building community in the investigation, planning, and scheduling of a program guiding the effective participation of all sectors of the community in a rationalized metric conversion of its measurement-sensitive design concepts, building regulations, standards, and related codes of practice.

During FY76, CBT will maintain and expand its involvement in the activities of the American National Metric Council (ANMC), and assist the ANMC Codes and Standards Sector and selected other sectors to develop: a U.S. plan for the conversion of building standards and codes to coordinate metric dimensions intended for implementation before start of the official U.S. metrication program; and a U.S. plan for the conversion of building standards and codes to coordinate metric dimensions intended for implementation after start of the official U.S. metrication program.

CBT will publish a report on problems facing various segments of the construction community to assist in a program of metrication for the industry. The Center

will develop talks individually tailored to each of several key groups, such as designers, contractors, product manufacturers, codes and standards organizations, public building agencies (Federal, state, and local), and labor, on their involvement in coordinated metric dimensions for buildings.

METRICATION AND DIMENSIONAL COORDINATION: A LITERATURE SEARCH

Robert Wehrli
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Sponsor - National Bureau of Standards

There is a great deal of literature and some bibliographies on metrication and dimensional coordination. However, much of the literature is obsolete (dating back to the 1940's), derivative (simply referencing other primary sources), or trivial. The purpose of this project is to produce a report supplying a limited number of abstracts that address crucial issues. Typical issues are: How can stocks of building materials with old "customary" sizes be coordinated with the new metric sizes? How can tradesmen be taught the metric system? How can dimensions be coordinated across types of products?

RESEARCH CONFERENCE ON THE BUILDING REGULATORY PROCESS

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Sponsor - National Bureau of Standards

A series of biannual workshops on the many aspects of the building regulatory process—each focused on a specified issue—provides a forum for researchers from industrial and academic organizations, as well as voluntary associations and public interest groups. The workshops enable them to consolidate what is known and to write a research agenda for what is not known. Findings will be conveyed to the research community, to professionals in practice, to concerned industries, and to government agencies. The workshops and associated publications provide visibility to this important influence on the evolution of building practice. The current lack of visibility has bred widespread suspicion about its legitimacy and its efficacy.

TECHNOLOGY FOR BUILDING STANDARDS AND REGULATIONS

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Sponsor - National Bureau of Standards

Building regulations (i.e., building codes and standards and design specifications) are the communications and control system for much of the building and construction in this country. The development of a way to formulate and express specification provisions that are clear, complete, and correct would have many benefits. In particular, it would be an aid to all building officials in developing a better understanding of the building regulatory and standards-generating processes. Also, the formulation and expression of specification, standard, and code provisions is traditionally a major expense in the building and construction enterprise—an enterprise that must absorb substantial losses if errors due to ambiguity occur.

Initially, project efforts will focus on the development of interim guides and computer aids for specifications, stand-

ards, and codes along with prototype application of the technology. The approach to be used in this program will include specific tasks to be carried out between various universities, architectural and engineering firms, and model code and standards organizations.

Last year, a contract "Technology for the Formulation and Expression of Specification," was awarded to the University of Illinois. Four areas of work have been pursued: (1) prototype algorithms for preparing outlines of specifications; (2) decision-table analysis and concepts for the logical formulation of specifications; (3) network representation; and (4) development of a user's manual for the computer program.

APPLICATION OF DECISION TABLES TO LIFE SAFETY CODE

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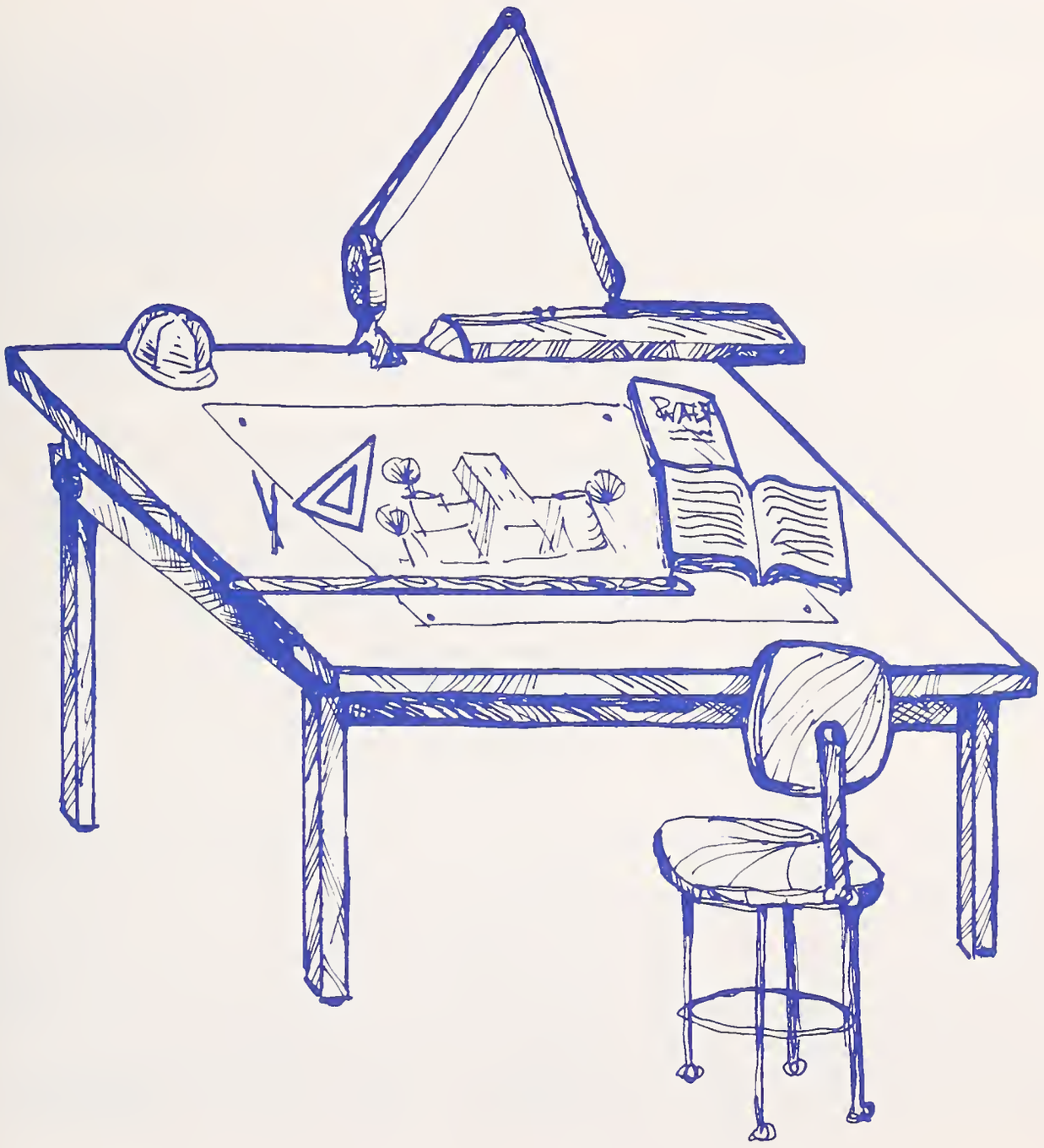
Sponsor - Department of Health, Education and Welfare

The need for clear, complete, and correct expression of specifications is obvious. Some of the agencies involved in the administration and enforcement of the Life Safety Code have expressed interest in the development of improvements to the code. Accordingly, the objective of this research is to determine the applicability of decision-table analysis to the decision activities of the Program for Design Concept in the Center for Fire Research.

The test project will address section 10-23 of the code, "Protection." The methodology employed will be the decision-table format using the decision-table algorithms and related procedures developed by the University of Illinois.

Housing and Building Technology



HOUSING TECHNOLOGY

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Sponsor - National Bureau of Standards

The housing technology effort is directed toward exploring those areas most useful in meeting critical housing needs. They include: (1) a need for the identification of research projects of a high-priority nature; and (2) the planning for research efforts to be undertaken in support of a solar energy program. The FY75 activities concentrated on defining high-priority research projects for housing, advancing mobile home research planning, and continuing investigations and planning, and residential applications of solar energy. Continued liaison with the Department of Housing and Urban Development and other organizations is instrumental in developing new high priority projects as part of a total research package for housing technology.

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT LEAD PAINT HAZARDS

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Sponsor - Department of Housing and Urban Development

Approximately 500,000 children below the age of seven years, have excessive levels of lead in their blood. Also, some 30 million dwelling units, currently occupied, were built before 1940 and probably contain some hazardous lead-based paint. The cost of lead paint hazard abatement may range from $200-$2,000 per dwelling unit. Public Law 91-695, The Lead-Based Poisoning Prevention Act, requires that the Department of Housing and Urban Development (HUD) carry out a research program to determine the nature and extent of the lead-based paint poisoning problem and means of its elimination. The Bureau is providing technical assistance to HUD in carrying out that program.

The lead paint poisoning project was established within the Center for Building Technology (CBT) to provide management for the overall effort. Personnel from CBT and the Bureau's Applied Mathematics Division are assigned to the project. The Bureau's Analytical Chemistry Division provides support in special areas. The wide variety of technical activities requires a truly interdisciplinary team and the staff includes professions such as: chemistry, mathematics, operations research, architecture, information science, engineering and others.

In FY75, the following major tasks were accomplished: (1) monitored a survey in Pittsburgh of 3,600 dwellings and 500 children living in those dwellings, for lead paint hazards and carried out data reduction and preliminary data analysis activities; (2) monitored HUD's field demonstration of lead hazard abatement methods in Washington, D.C., and Atlanta, Georgia, and evaluated the performance of the methods; (3) developed methods of analysis for an acerbic substance for use in paint as a deterent to ingestion; (4) carried out an information survey and developed a library on lead paint poisoning technology; (5) contracted for the design of a survey for lead paint in HUD's buildings; and (6) designed a field experiment to evaluate

alternative lead poisoning control strategies.

In FY76, the Bureau is: (1) evaluating a portable lead-detection instrument being developed under HUD contracts; (2) completing the analysis of the Pittsburgh survey and preparing plans for additional surveys; (3) monitoring and evaluating continuing field demonstrations of abatement methods and evaluating their cost-effectiveness; (4) evaluating additional acerbic substances; (5) monitoring CBT contracts for the preparation of survey and experiment designs and industry searchers for new abatement methods; (6) carrying out physical tests of materials submitted as potential abatement methods; (7) providing technical monitoring of HUD development contracts; (8) preparing new information prototypes on various aspects of lead paint poisoning for dissemination by HUD; and (9) designing an overall Clearinghouse program for HUD.

COMPENDIUM OF TEST METHODS USED IN OPERATION BREAKTHROUGH

David Waksman
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Sponsor - Department of Housing and Urban Development

This project is identifying laboratory test methods used to evaluate the innovative housing systems proposed for Operation Breakthrough and to prepare a document describing these test methods in such a manner that they would be of use to the housing industry. Operation Breakthrough was established by the Department of Housing and Urban Development to stimulate the development of residential construction concepts that would increase the housing production rate and thus assist in meeting the Nation's housing needs. Since many of the systems proposed by industry were innovative, extensive laboratory testing was required during the design and development phase of the Breakthrough Program to judge whether innovative designs would provide satisfactory performance during the life of the structure. In many cases, existing standard test methods could not be used and it was necessary to develop new laboratory procedures.

This project reviewed all test reports, and a compilation of test methods was developed. Test methods were organized by function and discipline, and the testing philosophy and rationale were included along with the specific test descriptions in the compendium.

PERFORMANCE STANDARDS FOR SPECIAL AND INNOVATIVE CONSTRUCTION

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Sponsor - Department of Housing and Urban Development

In support of the Department of Housing and Urban Development's (HUD) mortgage insurance program, there is a need for the development of performance-based standards to allow for the introduction of new materials and innovative designs in the construction process. Specific areas of research were identified as a result of Operation Breakthrough. Current HUD-sponsored research programs are oriented toward development of performance criteria and methods of evaluation. They are fed directly into draft performance standards. The performance standards

are intended to be responsive to HUD's needs and to provide equivalent performance as would be expected from use of the HUD Minimum Property Standards for conventional construction.

A draft of the performance standards in the format determined by HUD has been submitted for HUD's approval.

METHODOLOGY HANDBOOK FOR HOUSING SURVEYS

Stephen Margulis
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Sponsor - Department of Housing and Urban Development

In conducting four surveys of the Department of Housing and Urban Development's (HUD) Operation Breakthrough housing, the Center has developed a series of questionnaires. The four surveys are (1) work orders, (2) visitors, (3) "exit" (people moving away from Operation Breakthrough homes), and (4) occupants. Since it is apparent that these surveys would be useful for many other types of housing, this project will assemble these materials into a methodology handbook for use by others who may wish to conduct surveys. In some cases, the surveys could be used for basic information, with new sections added to give greater emphasis to a special topic such as security, safety, or lead paint poisoning; in other cases, the documents and methods could be adapted to other building types such as mobile homes, hospitals, or offices.

FIRE COMPENDIUM FOR OPERATION BREAKTHROUGH

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Sponsor - Department of Housing and Urban Development

A compendium summarizing the fire testing performed under the auspices of Operation Breakthrough was prepared for publication by the Department of Housing and Urban Development. This document describes in detail, the materials and system designs evaluated and the types of tests performed. Since many of the systems evaluated and tests performed were innovative, the compendium is of value to both the home building industry and organizations more directly concerned with fire hazards. The test descriptions were organized by type of test and housing system component; test methods and results plus component descriptions were included in the compendium.

COORDINATING FIRE STANDARDS RESEARCH-SUPPRESSION

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

Sponsor - Department of Housing and Urban Development

The Center for Building Technology is coordinating with the Center for Fire Research a project of fire standards research for suppression. This project is developing performance and engineering design data for automatic sprinklers to produce more cost effective design approach for non-commercial/industrial applications and to enhance the attractiveness of an automatic sprinkler for life safety. Automatic sprinkler systems are one of the best tools available for the protection of people from fire. Currently the cost of sprinkler systems for life safety is excessive as a

result of the over design developed for commercial and industrial applications.

The objectives of this project are: (1) develop design criteria for corridor sprinkler systems for fire containment; (2) examine existing performance specifications for sprinkler systems and components for potential cost reductions; and (3) study effects of automatic sprinkler operation on the physical and chemical (toxic) properties of fire effluent.

Work has been completed on the distribution of sprinkler water spray through door openings. A draft report has been prepared. Full-scale fire exposure tests also have been completed and the results are being analyzed for preparation of interim performance criteria sprinkler systems. Groundwork has been laid for sprinkler piping criteria by complete review of existing piping standards.

BUILDING TECHNOLOGY INFORMATION

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Center for Building Technology Headquarters - 301-921-3106

Sponsor - National Bureau of Standards

Information is the Center's ultimate product. This project is aimed at effective product delivery 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, the hosting of tours and conferences at the Bureau, and attendance at 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.

FEDERAL BUILDING TECHNOLOGY

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

Sponsor - National Bureau of Standards

This project is designed to effectively disseminate research to the Federal agencies, to coordinate Federal activity in building research, and to provide technology to assist Federal agencies. 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, maintaining a Federal building criteria reference service.

BUILDING PROCUREMENT WORKSHOPS

Harry Thompson - 301-921-3233

Sponsors - National Bureau of Standards;
Department of Health, Education, and Welfare;
General Services Administration;
Veterans Administration;
Department of the Army;
Office of Management and Budget;
National Aeronautics and Space Administration; and
United States Postal Service

In the past ten years, the Federal design and construction agencies, as well as others in the building community, have gone through a period of change that has seen new disciplines and management processes enter into the building community. Now that the building community has been in this transition period for a few years, the Federal agencies can evaluate the benefits of these activities and be ready to use and optimize them in making future choices. The need for evaluation of old and new methods has been expressed by Congress and the Comptroller General in some of their recent reports and legislation.

As a result, this project consisted of a jointly sponsored series of workshops entitled, "Answers for the Building Community." The specific workshops were: (1) The New Connection: Owners & Manufacturers, University of Wisconsin, Sept. 10-12, 1975; (2) Long Term Economy: A Systematic Basis for the Construction, Operation and Reuse of Buildings, Harvard University, Nov. 3-4, 1975; (3) Alternative Processes in Building Procurement, University of Illinois, Nov. 16-19, 1975; (4) Optimizing the Choices: A National Symposium, National Bureau of Standards, Mar. 24-25, 1976.

TECHNICAL AND SCIENTIFIC SUPPORT TO THE OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

Brian Pierman
Office of Housing and Building Technology - 301-921-3231

Sponsor - Occupational Safety and Health Administration

It is important that the Occupational Safety and Health Administration (OSHA) standards be based on data, observations, and research that technically substantiates a safe working environment. When this technical substantiation is not available, there are increased delays in issuing OSHA standards.

The diverse expertise, equipment, and laboratories of the Center for Building Technology (CBT) are thus being used to develop performance criteria and supporting research to meet OSHA objectives. In many instances, the identification of problem areas will result from discussion, consulting, and advisory assistance with CBT. In addition, CBT provides overall program management by providing a central focus between OSHA and the National Bureau of Standards (NBS) research community as implied in the interagency agreement between OSHA and NBS. CBT will, through this central focus, provide liaison, communications, and dissemination of research information as a routine basis and will monitor the progress of the work.

TECHNICAL AND SCIENTIFIC SUPPORT TO THE TRI-SERVICES COMMITTEE

Brian Pierman
Office of Housing and Building Technology - 301-921-3231

Sponsor - Tri-Services Committee

This project assists the Tri-Services Committee in their research and development of criteria and specifications. It also provides practical support to complete meaningful civil engineering tasks.

During FY75, eight other building research tasks were successfully completed for the Tri-Services Committee. In FY76, the following research projects have been funded (1) Earthquake-Resistant Design of Masonry Structures; (2) Evaluation of Elastomeric Roofing; (3) Investigation of

Waterproofing practices; (4) Building Joint Sealants; (5) Aluminum Wiring in Branch Circuits; (6) Underground Chilled Water and Heat Distribution Systems; (7) Field Testing of Reduced Size Venting; and (8) Consultative Services. Each of these studies has been described elsewhere in this report.

The Center's professional staff daily receive telephone calls from Tri-Services Committee personnel requesting advice. Typical of such requests are calls about the durability of calcium silicate and the heat transfer of calcium silicate, suitability of using protexluates (insulation), underground pipe criteria, hydraulic criteria, paints, coatings, adhesives and on structural related problems.

INTERNATIONAL BUILDING RESEARCH

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

Sponsor - National Bureau of Standards

The International Building Research Projects respond to foreign requests for technical literature on building research. The program supports complementary research programs, and exchanges of technical staff, provides participation in international conferences, and provides technical assistance to developing countries.

Liaison with the following organizations continues (1) U.S./French Cooperative Program, Centre for Scientifique et Technique du Batiment/Center for Building Technology; (2) International Council for Building Research Studies and Documentation (durability of materials, wind load, fire research, medical facilities); (3) cooperative program with the Building Research Establishment, United Kingdom (water supply and drainage, heat pumps, lighting standards for office building, and wind loads); (4) Ministry of Construction, Japan (U.S./Japan Panel on Wind and Seismic Effects); and (5) Institute of Research Technology, Brazil (training in building technology). The Center for Building Technology (CBT) provided technical evaluation assistance in an National Bureau of Standards/Agency for International Development survey of the state-of-the-art-of Philippine building technology. CBT participated in international organizations 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.

CENTER FOR BUILDING TECHNOLOGY/BRAZIL COOPERATIVE TRAINING PROGRAM

Harry Thompson
Office of Federal Building Technology - 301-921-3233

Sponsor - State of Sao Paulo, Brazil

The Center for Building Technology is providing, through a training program for a staff member of the Institute of Research Technology (IPT), Brazil, advice and assistance to increase his technical capability in building technology. As a result of his two-year training program—through direct involvement in research at the Center—this IPT staffer is expected to contribute to the improvement of building technology in the state of Sao Paulo, Brazil.

JOINT US/EGYPTIAN COOPERATIVE PROGRAM

James Haecker
Office of Housing and Building Technology - 301-921-3126

Sponsor - National Bureau of Standards

This project is to assist the Joint U.S./Egyptian Cooperative Commission by developing a cooperative program in building materials and building technology. The U.S./Egyptian Joint Study Group was formed and a meeting was held in Cairo in January 1975. A report of the Working Group on Technology, Research, and Development was published containing 29 projects to be considered. An Egyptian technical advisory committee was established and an introductory meeting was held with the Joint Study Group. The identification of U.S. and Egyptian professionals will continue for specific areas of technical exchange. The first visit of Egyptian team members in Building Materials and Technology was in May 1975. In addition, a National Bureau of Standards special Foreign Currency Program Grant was issued for a building information program.

PROGRAM EVALUATION AND PLANNING

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

Sponsor - National Bureau of Standards

This project serves as a focal point for liaison and planning coordination among the many Center for Building Technology (CBT) and other National Bureau of Standards (NBS) units involved in building research. This project includes such components as: (1) direct assistance to CBT and NBS on planning building technology activities; (2) advisory and technical evaluation committee activities; (3) project/program reviews to assess priority activities; and (4) graphic assistance to better communicate technical issues. It is expected to provide CBT and NBS with new directions in building research activities by developing improved research plans.

Also covered is industrial liaison with the building community. This includes the Center for Building Technology Advisory Committee, the identification of industrial research that shapes and influences the building process, and the development of an efficient and acceptable method for continued liaison with industry research directors and the management and technical staff of the Center for Building Technology. As part of this liaison, CBT staffers participated in scientific and professional conferences and seminars at NBS, National Academy of Sciences, National Science Foundation, American Institute of Architects, and various NBS information exchange seminars.

During FY76, an increased emphasis was placed on developing a long range plan and on liaison and research coordination between CBT and other NBS organizations concerned with buildings (Center for Fire Research, Center for Consumer Product Technology, Standards Analysis and Applications Division, Office of International Relations, Office of Information Activities, and others).

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Center for Building Technology
Institute for Applied Technology

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