Building Technology Project Summaries 1977-1978

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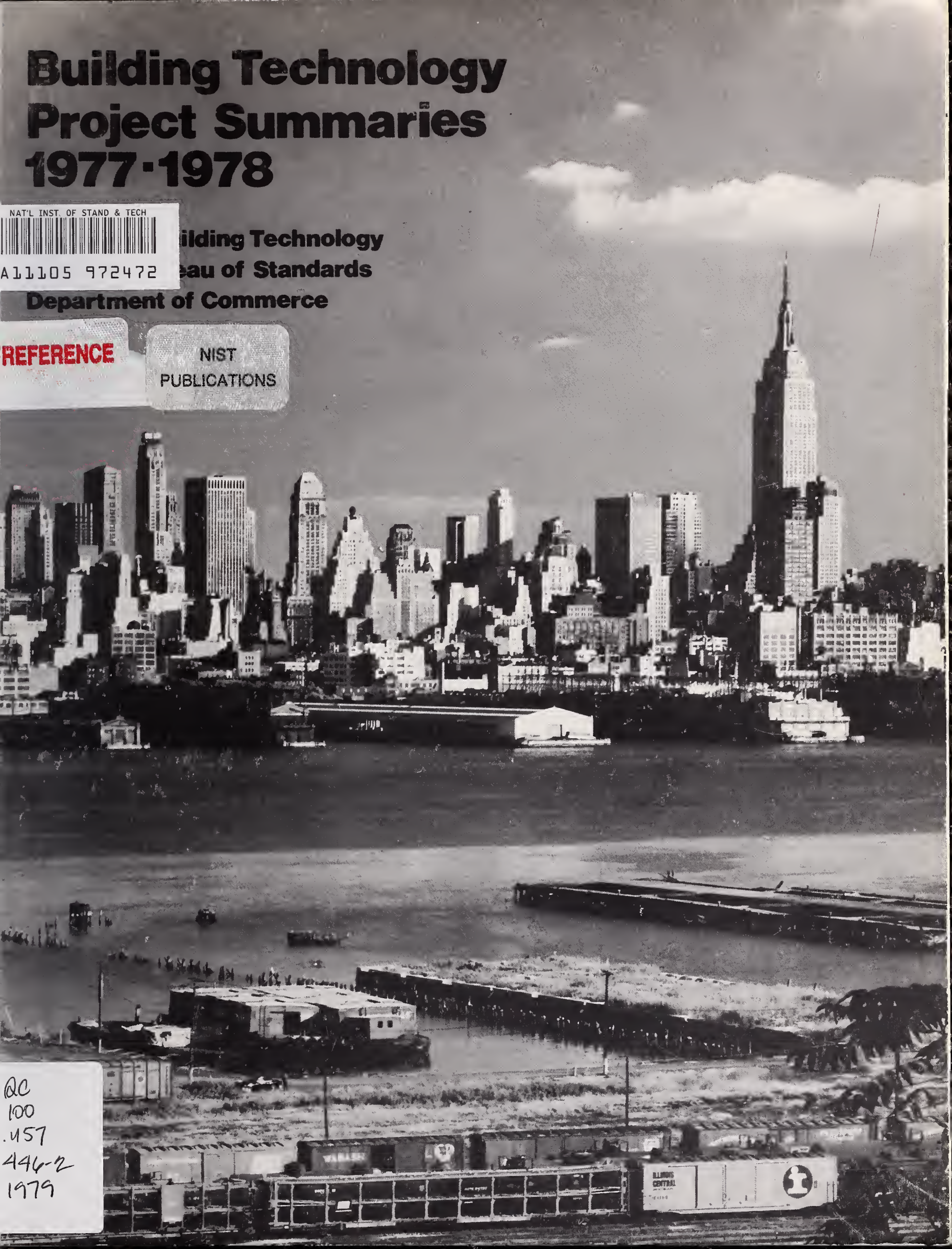

Building Technology Project Summaries 1977-1978

NBS SP 446-2

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Foreword

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

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

This report summarizes CBT's research for 1977-1978. 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 Center's approach to building research and its facilities. Special Publication 457-2, *Building Technology Publications, Supplement 2: 1977,* lists and indexes 1977 recent reports authored by CBT staff.

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

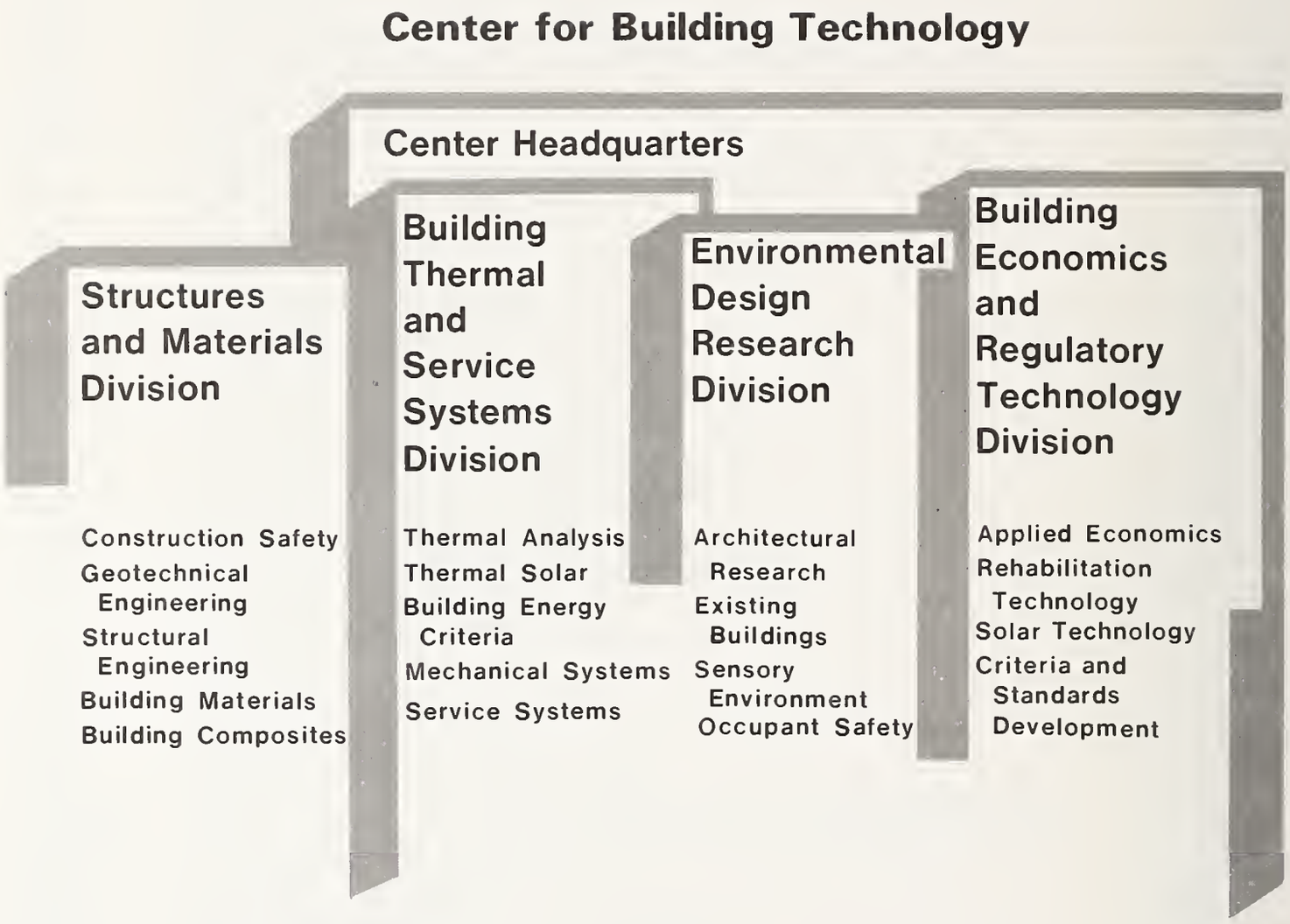
The Bureau's reorganization during April 1978 set in motion a reordering of its technical groups into more functional operating units. CBT was reorganized into four Divisions from three Divisions and two Offices. As a result of the Bureau's reorganization CBT's research activities on Energy Conservation in Communities are now being conducted in the newly created Center for Mechanical Engineering and Process Technology. CBT's organization is shown on page x.

Contents

Abbreviations Used in the Text

AIA	American Institute of Architects
ACI	American Concrete Institute
ANMC	American National Metrication Council
ANSI	American National Standards Institute
ARI	American Research Institute
ASPE	American Society of Plumbing Engineers
ASSE	American Society of Sanitary Engineers
ATMES	Advanced Technology Mix Energy System
ASHRAE	American Society for Heating, Refrigeration, and Air-Conditioning Engineers
ASME	American Society for Mechnical Engineers
BECC	Building Energy Conservation Criteria
BOCA	Building Officials and Code Administrators International, Inc.
CAL	University of California
CBT	Center for Building Technology
CFR	Center for Fire Research
CIB	International Council for Building Research Studies and Documentation
CSA	Community Services Administration
DoE	Department of Energy
EPA	Environmental Protection Agency
FCC	Federal Construction Council
FERC	Federal Energy Regulatory Commission
FHA	Farmers Home Administration
FIRL	Franklin Institute Research Laboratories
HUD	Department of Housing and Urban Development
HVAC	Heating, Ventilating, and Air-Conditioning
ICBO	International Conference of Building Officials
ICES	Integrated Community Energy System
IEEE	Institute of Electrical and Electronic Engineers
ISO	International Standards Organization
LBL	Lawrence Berkeley Laboratory
LCC	Life-Cycle Costing
MIUS	Modular Integrated Utility Systems
MPS	Minimum Property Standards
NAHB	National Association of Home Builders
NBS	National Bureau of Standards
NBSLD	National Bureau of Standards Load Determination (A Computer Program)
NCSBCS	National Conference of States on Building Codes and Standards
NDE	Non Destructive Evaluation
NEC	National Electric Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NIBS	National Institute of Building Sciences
NPS	National Park Service
NSF	National Science Foundation
OPSO	Office of Pipeline Safety Operations
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration

RIF	Resource Impact Factors
RILEM	International Union of Testing and Research Laboratories for Materials and Structures
RSV	Reduced-Size Venting
SAE	Society of Automotive Engineers
TE	Total Energy
USNC/CIB	United States National Committee/International Council for Building Research Studies and Documentation
VA	Veterans Administration
VSM	Vertical Support Members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Occupant Safety
Building Economics and Regulatory Technology Division
Applied Economics
Rehabilitation Technology
Solar Technology
Criteria and Standards Development

Energy Conservation

Residential heating systems are being evaluated by measuring the velocity and volume of air discharged from a heating register.

Energy Use in Building Operations

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Sponsor: Department of Energy

This project has been conducted in support of energy conservation criteria for incorporation in building energy performance standards. To be realistic and equitable, the criteria must take into account the effects on building energy consumption of several factors, including the ways that the occupants use or affect buildings and their energy requirements.

This project has produced two reports: "Review of Existing Data on Energy Use in Residential Buildings," and "Quantified Occupant-Use Factors Affecting Energy Consumption in Residences."

Building Energy Conservation Performance Criteria

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Headquarters

Sponsor: Department of Energy

During the year preceding the passage of PL 94-385, *The Energy Conservation and Production Act,* CBT was developing an energy budget concept for use in building energy performance standards under sponsorship of DOE and HUD. This concept was presented to the sponsors in September 1976 and has been widely discussed in government building construction agencies, the design professions, and selected professional societies. It envisions an eight-step approach to the preparation of performance standards for building, involving

1) a building classification scheme;
2) a climate classification scheme;
3) a data base on occupant discretionary use of energy in buildings;
4) development of typical models for a given class of buildings;
5) a data list on dimensional properties, occupancy characteristics, climate factors, and occupant energy-use factors;
6) an analytical procedure for optimizing the life-cycle costs of energy conservation measures and energy savings;
7) an adjustment of the on-site energy requirements to the corresponding resource requirements and their societal impacts; and
8) incorporation of an energy budget and other energy-related building performance requirements such as thermal comfort, illumination, air quality, water heating, and space into a performance standard for each major class of building.

Research and analysis has been carried out under the DOE/HUD sponsorship on each of these eight steps, with primary emphasis on residential structures. A principal step yet to be undertaken is the application of life-cycle costing techniques to the tradeoff between first cost and seasonal operating efficiency of heating and cooling equipment. This project entails optimizing the operating efficiency of heat pumps, furnaces, and boilers against cost, and using this analysis along with the output from the steps outlined above to calculate annual energy requirements for single-family dwellings in relation to

size, climate, and selected types of heating/cooling equipment.

Energy Conservation in New Buildings, ASHRAE 90-75

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Sponsor: National Bureau of Standards

CBT pioneered energy standards for new buildings for NCSBCS, who in turn requested ASHRAE and ANSI to develop a voluntary standard for use by NCSBCS and national, state, and local code groups. The preparation, promulgation, and implementation of this standard have occurred and the standard is now in use. It is the first national energy standard that has received wide acceptance. But these efforts must be continued if energy conservation design and construction is to be truly followed in the U.S.

In this phase of the work, problems of technical design, quantitative extrapolation of the standard's requirements, and general availability and workability are being studied.

The first revision of ASHRAE 90-75 has been drafted and has been sent out for public review before issuing it as a revised ASHRAE Standard and as a National Standard under ANSI procedures.

Energy Conservation in Existing Buildings, ASHRAE 100

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Sponsor: National Bureau of Standards

ASHRAE 90-75, *Energy Conservation in New Buildings,* is now published and in use. ASHRAE made the decision to first produce a standard for *new* buildings and immediately follow up with an energy standard for *existing* buildings—an area which offers the nation a much larger target for energy savings.

In this project, the results of research at CBT and at other places are being used to formulate energy standards for six different classes of existing buildings. All draft standards have been distributed for public review and comment before publication.

After production of the standards as ASHRAE and ANSI publications, the documents will be available for use by building code groups, government, and the private sectors. CBT has conducted an in-house review of these draft standards for DOE with special emphasis on the procedures for implementation. It is expected that the impact of these standards will be at least as significant as that of ASHRAE 90-75. When completed, these standards will be available for adoption by code groups and by the design and construction industries. The Federal government may use these standards for its buildings.

Effects of Resource Impact Factors

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Sponsor: Department of Energy

This project is in support of the DOE/CBT research program entitled "Building Energy Conservation Criteria," whose broad objective is to facilitate the development and implementation of energy conservation performance standards for the design and evaluation of buildings. The performance criteria being investigated under this program are expected to take energy prices into account. This project addresses the question of whether the energy prices used in developing standards based on these criteria should be the actual market prices paid or a price which has been adjusted to reflect the social value of energy resources. One method of making the required adjustments in market prices is through a system of multiplicative factors called "Resource Impact Factors" (RIF's). This project assesses the effect of using RIF's on the design energy consumption to be incorporated into performance standards and on the economic efficiency of such standards.

A preliminary CBT report has found that the use of RIF's could lower the energy consumption allowed under the standard by a significant amount. Under the present project, this report will be revised on the basis of comments and suggestions obtained from a broadly based public review and published in the NBS Building Science Series. Also, an article was published in the international journal, Energy and Buildings.

This project will provide those involved in the development of energy conservation standards with guidance in determining what factors are appropriate to be included in RIF's, how such RIF's can be integrated into the actual standards development process, and how the use of such RIF's would affect the standards being developed.

Energy Analysis: Manchester Building

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Sponsor: Department of Energy

The Norris Cotton Federal Office Building in Manchester, New Hampshire, is a seven-story, medium-size office building that was designed to demonstrate many energy saving concepts. The lower three floors use a system of heat pumps which, in winter, remove excess heat that builds up in the interior core and "pumps" it to the perimeter areas where it is needed for space heating. The upper four floors use various types of fan coils, radiators, and variable air-volume units for heating and cooling. Thermal energy is supplied to the building by modular gas boilers, oil-fired boilers, solar energy, and an engine-driven generator that provides both electricity to operate an electric chiller and hot water to drive an absorption-type chiller. In addition, the building uses heavy masonry construction with exterior insulation, double-glazed windows of relatively small area, and thermal storage. Thermal analysis of this building, therefore, would provide a unique opportunity to examine the relative effectiveness of several different energy saving concepts all operating under identical

climatic conditions.

To do this, a computer control system has been installed at the building site. It gathers data from several hundred sensors that measure air and water temperatures, fluid flow rates, solar radiation, and electrical power consumption. This information is then recorded on magnetic tapes that are sent to CBT for input into a central computing facility. Here the raw data are reduced to provide information on energy usage and equipment effectiveness.

The information will be tabulated and, together with all significant findings and results, published in the form of quarterly, special, and progress reports and also made available to the general public through news releases, magazine articles, and NBS publications.

The end result should be a better understanding of how to design and construct a building which is not only energy conserving but cost effective as well. As new buildings are erected, this will translate into a direct savings of the Nation's energy.

Performance Analysis: Manchester Building

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Sponsor: Department of Energy

Energy conservation is one of the most important avenues to be pursued to obtain near-term solutions to the current U.S. energy problem. Since approximately one-third of the Nation's energy is used in and around buildings, it is particularly important to develop good energy conserving practices in the design, construction, and operation of the Nation's buildings. This project provides a unique opportunity to gather data on the actual performance of a medium-sized office building designed specifically with energy conservation in mind.

Under this project, CBT will obtain actual energy consumption data on the Norris Cotton Federal Office Building in Manchester, New Hamsphire, as a whole and on its systems and components (including solar). We will also evaluate user acceptance of the various design features as well as operational modes of the building that have been instituted for the sake of energy conservation. The illumination systems, their power consumption, and related performance will also be evaluated. A comparative life-cycle-cost analysis of this particular building against a hypothetical reference building of conventional design will also be made.

During the conduct and at the completion of this project, the research results will be widely disseminated so that the major conclusions derived from the project can be rapidly implemented in both government and private building design, construction, and operation.

Energy Conservation in Blended Cement

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Sponsor: Department of Energy

The manufacture of portland cement consumes about 2 percent of the energy consumed by the Nation's industrial processes. As much as 20 percent of the energy consumed by the cement industry could be conserved by the increased production of blended cements.

In this project, the behavior of blended cements and concretes containing fly ashes and blast furnace slags are being compared with those of portland cements and portland cement concretes to develop relationships between position, microstructure, and performance. These relationships will form the basis for developing performance-based standards for blended cements, and for fly ashes and slags added to concretes. In addition, CBT is participating in ASTM committees concerned with cements (C1) and waste materials (E38). Through this participation, it is playing an active role in the establishment of performance tests and criteria for blended cements and for broadened use of waste materials in construction.

Weatherization Demonstration

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Sponsor: Community Services Admininstration.

To help poor people cope with the high and increasing costs of energy, the CSA wants to predict savings through optimum weatherization of homes of the poor in all parts of the U.S. This information will allow CSA to more effectively distribute Federal funds across the country, to avoid the extra expenses incurred by having to go back to houses for further weatherization, to predict the savings in fuel and money that can be achieved by the program, and to consider a loan program as a source of additional money for weatherization. Because wide variation has been observed between calculated and field measurement data on possible energy savings, CSA has decided that it wants to obtain field data as a basis for predicting maximum energy savings. To gather this field data, CSA has decided to conduct a national demonstration on energy savings through weatherization of low-income owner-occupied homes.

CBT's support includes selecting sites, homes, and weatherization options; supervising the collection of data from the demonstration homes; and analyzing the results of the demonstration. During this fiscal year weatherization options will be installed in as many homes as possible across the U.S. and their effectiveness evaluated. The homes will be selected across 16 climate zones and be representative of the types of buildings, constructions, and heating system in each area. Computer modeling, cost estimating, and field inspection will be used to select the most cost-effective package of weatherization options for each climate zone and building type in the sample.

Computerized Climate Data

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Sponsor: Department of Energy

Since accurate building-energy prediction is necessary for energy conservation in design, and energy prediction is increasingly performed by computer, accurate and economical computerized climate data is extremely important. In this project, the influence of each climatic parameter (temperature, humidity, sun, wind) on energy is being analyzed by multivariate regression from a data base on the energy use of several buildings calculated hourly for as many as 60 locations across the U.S.

This work will be a major step in building energy prediction, both in reducing analysis costs and improving accuracy, and should foster more optimization in design.

Federal LCC Guide for Energy Conservation

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Sponsor: Department of Energy

CBT has analyzed all the life-cycle costing procedures used by Federal agencies for evaluating modifications to existing buildings and designs for new buildings. The survey provided a basis for establishing life-cycle costing guidelines for energy conservation projects in Federal buildings. Drafts of two reports—the survey of LCC practices and of the LCC guidelines—were delivered to DOE.

Products for FY78 include a revision of the LCC guidelines in response to comments received from DOE and other Federal agencies and a report on LCC guidelines.

Building Illumination Systems

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Sponsor: Department of Energy

Energy used to provide illumination is estimated at 5 percent of national consumption and perhaps 20 percent of the total used in buildings. Significant energy savings could be realized by a reduction in illumination levels to the minimum required for safety and efficiency. Serious disagreement exists on the appropriate levels to be specified, how they will be measured, the interaction with other building systems (heating and ventilation), safety codes, and the substitution of natural for artificial light.

This project will use the knowledge of experts practicing in the field to recommend an interim set of criteria for energy-conserving building illumination, identify the restrictions upon promising improvements imposed by existing codes and practice, determine significant gaps in illumination knowledge and equipment, and perform or encourage research and development in these areas. The result will be a set of recommended energy-conserving building illumination criteria, including an energy-budget method and analysis.

These criteria will be submitted to one or more professional organizations for sponsorship through the voluntary consensus standard process. Physical measurement techniques for illumination components and systems will also be developed and published.

Simplified Daylighting Calculations

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Sponsor: Department of Energy

Although it has been shown by a simplified calculation scheme that daylight could make the window an effective element for building energy conservation, the accuracy of the daylight calculations based upon the simplified approach has been questioned. Two more comprehensive and supposedly accurate computer programs are GLIM and LUMEN II. These programs will be procured and used to check the results for the simplified calculations for various room designs and window designs. A report will describe calculation results and comparative analysis between the comprehensive and simplified daylight calculations. The simplified calculation routine, if validated, will be made a part of NBSLD to allow the calculation of annual energy savings due to the use of daylight. More reliable energy conservation criteria for window design will be possible once this project is complete.

Simplified Load Calculations: Project Conserve

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Sponsor: Department of Energy

Project CONSERVE is a computer-based cost-and-savings questionnaire system administered by state officials under the sponsorship of DOE to assist homeowners in evaluating the effectiveness of various energy conservation options. To be effective, the heating and cooling load program used in the CONSERVE system should be fast, simple, and yet accurate. CBT is developing a simplified version of NBSLD that can fit into the cpu time requirement of 3 seconds (UNIVAC 1108) instead of the 3 minutes usually required by NBSLD. The results of this simplified program will be validated for accuracy by NBSLD runs on typical houses. The subroutine will be compatible with the data string generated by the main program of Project CONSERVE that is being developed by Applied Urbanetics. This simplified program will be used by the state officials to inform homeowners of possible energy savings by various retrofit options. The final program is considered essential to the success of Project CONSERVE.

Thermostat Specifications for Military Housing

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Building Thermal and Service Systems Division

Sponsor: Department of Navy

The Navy is currently replacing thermostats in its residences, barracks, and office buildings. New thermostats with energy saving features can be applied to these buildings to save energy. A purchase specification with energy saving data would not only improve the quality of the buildings but also provide a significant amount of energy savings.

To this end, CBT is investigating all thermostats on the market, and is categorizing, comparing, and quantifying their construction and performance. The energy savings and cost-effectiveness of new thermostats (such as clock thermostats for night setback) are also

being studied. The result of this research will be a specification for purchasing thermostats.

MIUS Program Management

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Sponsor: Department of Housing and Urban Development

The Modular Integrated Utility System (MIUS) concept addresses the increased cost of community utilities. The MIUS concept of integrating the facilities for providing electricity, space heating, space cooling, domestic water heating, solid waste processing, and wastewater treatment has a potential to reduce the life-cycle cost of these utilities while reducing fuel energy consumption by up to 50 percent. For this latter reason, MIUS is a legitimate part of the national energy conservation program.

It has been estimated by HUD that the domestic market for MIUS is on the order of 16 percent of new construction. An even stronger foreign market is predicted. A domestic savings of 2.5 million barrels of oil per month is possible based upon the above market capture. Residential utility operating costs are projected to be $60 billion in 1986, indicating a significant potential for cost savings.

Since a MIUS is most cost-effective when installed in phase with new construction and has a significant potential as a near-term (pre-breeder) technology to reduce energy consumption, rapid demonstration and deployment of the technology is important.

The products of this project will be a catalog of MIUS-related projects in countries; a Final Report of the CCMS-MIUS project; talks, journal articles and seminar materials on MIUS applications, design techniques, and economics; and a report on the performance of a grid-connected total energy plant.

Standards for Solid Waste Sampling

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Sponsor: National Bureau of Standards

There are no nationally recognized methods for the field sampling and laboratory analysis of refuse and refuse-derived fuels. Technical specialists in bomb calorimetry are greatly concerned about the sample size required for determining the heating values of refuse. The challenge is to provide reliable methods of laboratory-based ASTM-approved methods. This project will identify the research needs and technical issues that need to be addressed in applied measurement technology for solid wastes and refuse-derived products. CBT will also determine the performance characteristics of laboratory equipment to establish consistent, replicable laboratory analysis. The center will also develop a data base of technical information, procedures, and test methods. An important part of this will be determinations of the chemical and physical properties of field samples of solid waste and refuse-derived products. These factors will foster their acceptance and use as alternative fuels.

MIUS Demonstration

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Sponsor: Department of Housing and Urban Development

In the residential construction industry each new project represents a significant financial risk to the developer. Since developers do not desire to compound this risk, they innovate slowly. A full-scale demonstration of a new concept or technology can provide sufficient data to permit investors to appraise the cost effectiveness and risks of the concept. The Modular Integrated Utility System (MIUS) is a new concept which, according to numerous analytical studies, has a potential for saving energy for reducing life-cycle cost of the basis utilities needed for communities.

The major NBS activity in this multi-agency demonstration effort has focused on a detailed review of the site developer's conceptual and preliminary designs for conventional utilities and a MIUS. As a part of this review, many independent analyses were developed addressing technical options, cost of production, thermal balance, energy sales rates, building energy demand and consumption, and the financial viability of different design options.

Total Energy Demonstration Analysis

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Sponsor: Department of Housing and Urban Development

Total energy (TE) systems (also known as cogeneration systems) have the potential for significant energy savings over existing modes of separately supplying electricity, space heating and cooling, domestic hot water, and industrial process heat. An estimated 600,000 barrels per day oil can be saved in certain industrial sectors alone through use of this technology.

The technical approach under the HUD-MIUS Program is to install instrumentation, collect and analyze data, and evaluate a diesel total energy plant serving a residential development in Jersey City, N.J.

The major objectives of the program are:

1. To establish a performance concept for total energy systems
2. To collect and disseminate data from an operating total energy plant
3. To develop methods of analysis for total energy
4. To conduct an overall evaluation of total energy

The impact of this effort will be the availability, for the first time, of detailed data on the performance of an actual operating TE plant. This will allow designers to design better TE systems and to compare conventional systems on a basis of actual, not hypothetical, system performance. Developers and utilities will be able to appraise the cost effectiveness and risks of TE in a clearer fashion based on the data being collected. The Federal government will be able to properly assess the costs and benefits of TE and formulate effective means for its encouragement.

ATMES Technical Advisory Support

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Center for Mechanical Engineering and Process Technology

Sponsor: Department of Energy

DOE is planning major research activities in the area of integrated utility systems as part of their community energy conservation program. The technologies include total energy and cogeneration, solid waste conversion to energy, community planning, district heating, and other associated technologies. The multi-million dollar efforts being undertaken at the Argonne National Laboratory in the ATMES (Advanced Technology-Mix Energy System) and ICES (Integrated Community Energy System) Programs in support of DOE should draw on the experience developed since 1970 in the HUD-MIUS Program.

Products include technical reviews of ATMES draft reports, planning documents, and data and research results from the HUD-MIUS and HUD-Total Energy Demonstration efforts. The impact of this project will be a strong and viable Federal research effort in technology development for community energy systems under DOE. The data, methods, and evaluations available from these Federal research efforts will lead to improved technical and economic bases for decision-making by private utilities.

Technical Support to BECC

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Sponsor: Department of Energy

Significant reductions in energy conservation in buildings can be achieved through improved practices. However, the technical and institutional aspects of these practices (design, construction, and operation) are many and require comprehensive analysis. The approach to this activity is to provide technical services in support of DOE, which has overall responsibility for the research, development, and demonstration of energy efficiency in buildings. This effort is integrated with the NBS responsibility for technical management of the research-based DOE/NBS Building Energy Conservation Criteria (BECC) program.

In carrying out this effort, specific tasks are identified and defined for NBS involvement in activities generally performed by others, but for which CBT has expertise or programmatic need-to-know. Effective performance results from an inter-disciplinary approach oriented to energy conservation in buildings.

The products of this activity frequently take the form of written recommendations and comments intended to improve draft documents prepared by others. While primarily directed to the sponsor, comments and recommendations are also shared with others toward the objective of helping to shape a consensus for constructive support of overall national objectives.

All segments of the building community are keenly interested in the development of performance criteria for energy conservation in buildings. Energy conservation in buildings has become a dominant issue in the arena of public policy. As DOE requirements become defined,

this effort will support the implementation of state energy development plans under P.L. 94-163, and development of improved energy performance criteria.

Criteria for Retrofit Materials

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Sponsor: Department of Energy

This project covers criteria for retrofit materials and products used in making existing buildings more energy efficient. Although this project is sponsored by DOE and is an important part of their weatherization program, the information is of value to anyone interested in retrofitting residences or in selecting retrofit materials and products. Because of the need for energy conservation and the fact that over 40 million residences in the United States are not adequately insulated or weatherized, the results of this research will be distributed to researchers, manufacturers, consumers, contractors, Federal, state, and local government agencies, particularly those involved with energy conservation programs, specification and standard writing organizations, and professional and technical societies.

Installation Standards for Energy Retrofit

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Environmental Design Research Division

Sponsor: Department of Energy

This project will collect technical back-up data and the preparation of draft installation standards for individual measures, such as insulation and window devices. The project also covers—within the limits of funding provided, the review of relevant reports and guidelines prepared by others. Specific tasks undertaken as part of the project are:

1. Develop installation guidelines for reflective, rigid board, urea formaldehyde and duct insulation;
2. Prepare guidelines for replacement oil burners;
3. Complete installation guidelines for replacement windows, storm windows and thermally improved glazing;
4. Review reports on installation guidelines on vent dampers, ignition devices and other retrofit measures as prepared by others.

The project is being carried out through a cooperative effort of architects and engineers that are addressing the building envelope (fenestration and insulation) and mechanical systems.

Prioritizing Housing Retrofit Measures

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Sponsor: Department of Energy

The objectives of this project are to develop; a) several matrices prioritizing various retrofit measures for existing buildings (1-4 dwelling units) and mobile homes, in relation to climate, economic criteria, cost of alternative energy sources, and building design variables in support of the utility retrofit program in the proposed National Energy Act; and b) methods for adjusting priorities to local costs for energy, labor, and materials. Using modifications of the Project CONSERVE

computer program, this project will calculate annual energy savings for various retrofit measures for residential buildings. Analysis will cover representative cities in all U.S. climatic areas, for typical energy costs, material and labor costs, and useful life. Retrofit measures will be prioritized in terms of a suitable economic measure for 1-4 family buildings and mobile homes, and supplied to utility firms to illustrate process for uniformity in approach.

Performance of Retrofit Insulations

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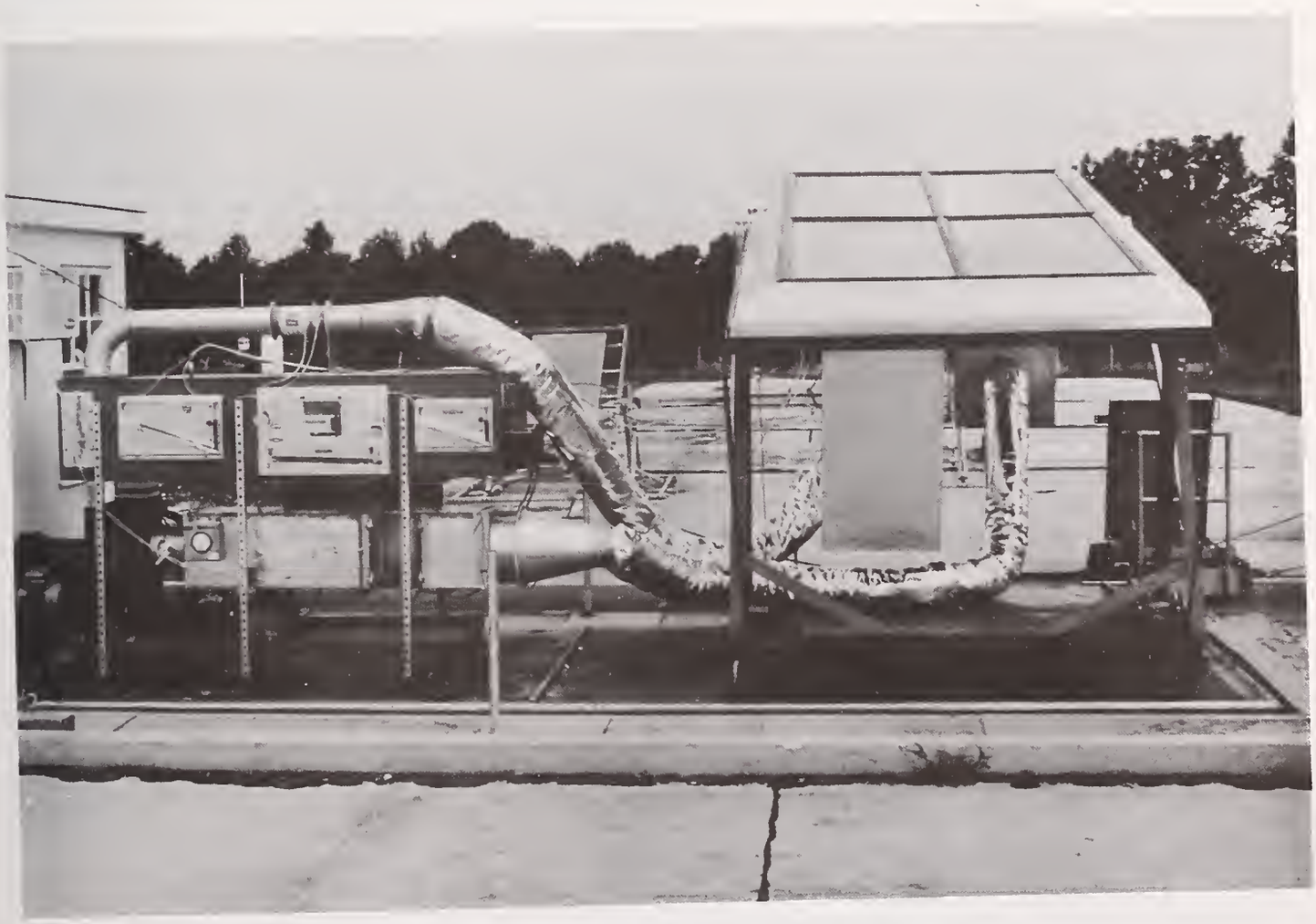
Structures and Materials Division

Sponsor: Department of Energy

Older homes without insulation in their exterior walls are being insulated because of high heating costs and the need to conserve energy. The common insulating materials used to retrofit walls are loose-fill cellulose, loose-fill mineral fiber and urea-formaldehyde based foams. Comprehensive field surveys have not been conducted to document the performance of these retrofit insulations in service. Potential problems may occur including settling of loose-fill materials, shrinkage of foams, excessive moisture accumulation, and poor workmanship during applications. Data need be gathered so that a proper assessment of the performance of insulations used to retrofit exterior walls may be made.

Results of this research will be used in connection with the DOE Weatherization Program for low income housing and with other building energy retrofit programs. In addition, the results will be distributed to researchers, manufacturers, consumers, contractors, federal, state and local governmental agencies, specification and standard writing organizations, and professional and technical societies. Talks will be presented at conferences and symposiums sponsored by such organizations as ASTM, ASHRAE, and insulation contractor associations. Specific activities will be undertaken in consultation with the sponsor for dissemination of the results.

Solar Energy



This test equipment for air heating solar collector systems is located at the NBS solar field site.

Commercial Solar Energy Demonstration

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Sponsor: Department of Energy

In view of the energy crisis and the increasing rise in the cost of fossil fuels, DOE began a cooperative program with CBT to determine the feasibility, use, and performance characteristics of commercial solar energy systems and buildings using such systems.

An interdisciplinary team, organized from CBT staff members, participated in the preparation of draft standards and performance criteria and will participate in the evaluation of demonstration system performance. Experience gained from the evaluation will be fed back into the development of improved criteria. The evaluation process during the demonstration program will involve comparisons of actual with predicted system and component thermal performance, the evaluation of operational problems (accidents, equipment failures, etc.) and the examination of institutional constraints (e.g., code problems).

Data being collected for the commercial demonstration program are being reviewed for information concerning the possible problems encountered in the design and construction of the demonstration units due to the existing building regulatory codes. An initial report on the findings will be prepared. In the end, this project will ensure that solar powered equipment does not adversely affect public health and safety, that it provides satisfactory reliability and performance, and that solar systems will be accepted with confidence by the consumer.

Solar Energy Program For Housing Systems

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Sponsor: Department of Housing and Urban Development

This project will help ensure that solar-powered equipment will not adversely affect public health and safety. It will also develop regulations and testing methods to bring reliability and performance standards to the solar marketplace. Experience gained from the evaluation of system performance will be fed back into the development of improved criteria. The evaluation process during this demonstration program will involve comparisons of actual with predicted systems and component thermal performance, the evaluation of operational problems (accidents, equipment failures, etc.) and the examination of institutional constraints (e.g. code problems). It is through these steps that solar systems can become fully accepted. This project continues the CBT-HUD cooperation in solar studies that has been continuing since 1974.

Solar Hot Water Test Program

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Sponsor: Department of Energy

The principal objective of this project is to provide experimental data under controlled conditions for the evaluation of selected analytical models as well as test methods proposed by ASHRAE Project Committee 95-P for solar domestic water heating systems.

The first step will be to review the existing widely-used computer programs such as TRNSYS, f-chart, and Solcost to identify assumptions made concerning tank stratification, tank and pipe thermal losses, and heat exchanger effectiveness. In addition, a survey will be made to identify the important types of solar domestic water heating systems to be addressed in this project. Second, a number of laboratory tests will determine the extent to which the assumptions in the relevant computer programs are valid. Tests will be conducted in those situations where sufficient uncertainty exists about the computer program routines and assumptions being analyzed.

The review and laboratory experiments will be used to identify a small number of complete systems to be installed in the field for controlled experimentation. The primary purposes of this task will be to run selected systems for at least 12 months and compare the test results with predictions made by the computer programs, and perform standard tests on the system as proposed by ASHRAE Project Committee 95-P.

Solar Commercial Handbook

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Sponsor: Department of Energy

Building owners, builders, architects and engineers, lenders, manufacturers of solar energy equipment, and research analysts all need a convenient, inexpensive method for determining if solar energy is an economically viable approach to space heating and domestic water heating in commercial buildings. The purpose of this project is to provide information on the economic feasibility of solar energy systems. This is to be done by preparing and disseminating a report and handbook on the economic performance of well-defined solar heating and hot water systems in selected types of office buildings in different regions of the U.S. This information will promote interest in the use of solar energy and reduce the uncertainty associated with its use.

Passive Solar Data Requirements

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Sponsor: Department of Energy

This project will establish the thermal performance factors to be used in evaluating various types of passive solar heating and cooling systems. It will also determine the requirements for measured data, which includes the type of measurements to be made and their accuracy range and frequency. CBT will also identify the instrumentation required for monitoring the building system and major components for extended time periods (includes sensors, data acquisition and recording apparatus), and will recommend data analysis techniques,

reporting format, and information disposition methods. Emphasis will be placed on surveying the various kinds and types of passive systems in an attempt to classify them into categories. In addition, the results of all experiments where passive systems have been instrumented and data reported will be reviewed to determine the experimental techniques that have been used in the past.

The output of this project will be a report to the Department of Energy outlining the recommended procedures for doing an experimental evaluation of passive buildings. The implementation phase will involve the Department of Energy's requiring that all research contractors follow the recommendations in evaluating their buildings. In addition, it is the intent to have all passive buildings in the national demonstration program be evaluated using the procedures. Depending on the success of the project and the experience gained over the next several years, the procedures could ultimately be adopted as an ASHRAE test standard for such buildings.

Collector Durability and Reliability Test Program

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Sponsor: Department of Energy

The reliability and long-term performance of solar collectors has not generally been demonstrated. Recent studies have indicated that significant changes in collector performance (greater than 10 percent) can occur as a result of exposure to "no-flow" conditions for three to nine weeks. A number of component and materials tests have been proposed as a means to evaluate the reliability/durability of solar collectors. However, these testing procedures have yet to be proved. This project is intended to provide a coordinated testing program that will result in the establishment of validated testing procedures to relate laboratory, accelerated field, simulated operational exposure, and actual field demonstration data for solar collectors used in building heating and cooling applications.

A review of existing and planned testing procedures useful in evaluating the reliability/durability of collector units and their materials will be conducted and a detailed program plan will be prepared. Laboratory and outdoor field exposure tests will be performed on solar collectors and their materials. The results of these tests will be correlated and compared with actual in-use performance. Long-term field exposures will be conducted at a number of different sites to evaluate climatic effects. Test specimens representative of various collector types will be used.

Validated testing procedures for predicting the reliability/durability of solar collectors and their materials can be incorporated into the solar performance criteria and MPS documents that CBT is responsible for. In addition, they will be submitted to ASTM and other concerned organizations for adoption as consensus standards.

Standards for Solar Cover Plates

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Sponsor: Department of Energy

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

Many standard test methods are available to evaluate materials such as glass and plastic. However, the performance requirements for cover plates of solar collectors are not entirely covered by the existing test methods. The purpose of this project is to prepare a draft performance standard for cover plate materials for flat plate solar collectors.

Initially, performance criteria, performance attributes, degradation factors and currently available tests will be identified. Tests will be assessed to determine if modifications are necessary to reflect in-use solar conditions. Laboratory studies outdoor weathering exposures will be performed to obtain data needed to prepare definitive test standards. Draft standards will be prepared in conjunction with ASTM committees and submitted to ASTM for consideration as consensus standards.

Standards for Solar Seals

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Sponsor: Department of Energy

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

Thermal Test Methods for Solar Components

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Sponsor: Department of Energy

Standardized testing procedures for solar collectors and thermal storage devices have been proposed by CBT. Three test stands for conducting outdoor tests of solar collectors and a laboratory facility for testing of thermal storage devices have been constructed. A round-robin test program consisting of testing two solar collectors at NBS as well as at 20 other independent outdoor and indoor testing facilities at sites around the United States has been conducted. The purpose of the round-robin test series was to determine the feasibility of the collector test procedure and to compare the results of test conducted in different geographical locations as well as with natural and simulated solar radiation.

Testing has been completed on 6 different manufacturer's collectors and a 1.9 m^3 (500-gallon) water tank in the CBT test house. Additions have been made to the solar collector test procedure as originally proposed to allow for the determination of the collector "time constant" and "incident angle modifier." The test procedures for both solar collectors and thermal storage devices have been adopted by ASHRAE as Standards 93-77 and 94-77, respectively. All test data taken as part of the round-robin test program have been analyzed and will be published.

Tests will be completed on additional solar collectors that can be identified to have unique characteristics which might possibly influence the solar collector test procedure. Alternates or additions to the present collector test procedure will examined including: all-day testing, relative-type testing using a standard collector heat-loss factor, correction factors to correct all data to some standard conditions, and the effect of using alternate heat heat transfer fluids such as oils for the test. Thermal storage tests will be completed on a pebble bed storage device and a phase-change storage device both using air as the heat transfer fluid. All project findings will be used directly by ASHRAE to update Standard 93-77 and 94-77.

Standards for Solar Collector Insulation

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Sponsor: Department of Energy

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

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

consideration as consensus standards. The research findings will provide the basis for evaluating insulation materials for solar collectors, improve the basis for selecting insulation, and further the development of better insulation materials.

Standards for Solar Absorptive Coatings

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Sponsor: Department of Energy

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

The purpose of this project is to prepare such draft standards. These standards will be based upon results of laboratory studies and will be submitted to the ASTM for consideration as consensus standards. The research findings will ensure improved absorptive coatings performance, provide a basis for selecting proper materials, and enhance acceptance of solar systems by making the systems more reliable.

Standards for Solar Materials: Problem Definition

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Sponsor: Department of Energy

Solar heating and cooling systems are unlikely to be widely accepted until performance requirements are quantified in the form of standards and compliance with these performance requirements is demonstrated. This project will identify the studies needed to develop such materials standards. The CBT approach is to identify available solar systems that are currently in-service; identify materials used in the available systems that may exhibit problems; identify by communicating with manufacturers and other knowledgeable sources and actual field inspections, the materials problems that are being experienced; identify currently available materials standards and assess the standards to determine their applicability for use in solar systems; identify needs for new standards; make recommendations for future laboratory studies; and prepare tentative guidelines for the selection of materials. An initial report NBSIR 77-1314, *Solar Energy Systems-Survey of Materials Performance,* has been distributed to DOE, other Federal agencies, and standards-setting groups such as ASTM for use in the development of materials standards.

Non-Instrumentation Data Center—SHACOB

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Sponsor: Department of Housing and Urban Development

Prior to actual operation of the Solar Data Center (SDC), a prototype system was constructed to prove the feasibility of the "design" for the data base. When it was satisfactory to SDC users and developers, the SDC at NBS began formal operations. Once the design of the data files had been determined, procedures were developed for data to be transformed into machine-readable inputs, programs were written to produce computer reports of the data and the reports are now being disseminated on a regular basis.

The data base consists of six files of technical and non-technical data, collected by various HUD subcontractors. Each file is in a different stage of implementation. As data are collected to populate the computer file, feedback from the users of the data allows us to upgrade programs and procedures that relate to the data. In FY 78, the design of the data base will integrate the separate files into interrelated files to better service the needs of the SDC users. More user-oriented interfaces to the data base will be developed to allow the remote user access over a terminal. Programs will be developed that display the technical information for CBT scientists to use in their evaluation studies. The Franklin Institute Research Laboratories (FIRL) are responsible for dissemination of the data to other technical groups and the general public. Frequent interaction will be needed between SDC, FIRL and the data users to assure the quality of data and services.

Development of Solar Regulatory System

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Sponsor: Department of Energy

To make solar energy a viable and maturing nondepletable energy source for the Nation, the regulatory system must not impede technical development. At present, the model building codes do not address solar energy and there is no definitive plan in existence for the establishment of an overall solar regulatory system.

This project will address the short term needs of the Nation by developing interim solar provisions that could be processed through the three model code organizations for eventual adoption by the using jurisdictions. In addition, a long range plan will be developed to identify a definitive solar system including research needs, implementation strategy, training requirements, etc. This effort will be conducted through contacts with regulatory and professional organizations under the management and guidance of CBT.

Standards for Rubber Hose & Connections

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Sponsor: Department of Energy

Rubber hose is an economical and efficient connector in solar energy systems between the solar collectors and manifolds on the supply and return lines. Also rubber hose is sometimes used at the inlet and outlet of pumps, storage tanks, and other components in the system. At present, however, there is no standard for hose used in solar systems.

The environment and other conditions surrounding solar energy systems necessitate a high quality hose having a long life, good resistance to ozone and other atmospheric pollutants, and retaining good performance at high and low temperatures. Standard methods of testing hose for most of these characteristics are given in ASTM D380-77. The principal task here is to establish minimum requirements for the hose, based on these tests, to assure satisfactory performance in solar energy systems.

The approach will consist of identifying performance requirements, important properties related to performance, factors which could affect the performance and existing tests to measure performance of rubber hoses and connections. Laboratory studies will be performed to determine if materials meet the requirements and to develop procedures, as needed, to measure performance. Based on the laboratory studies, draft standards will be prepared.

Standards for Nonmetallic Containment Materials

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Sponsor: Department of Energy

Standards for materials used in solar heating and cooling systems are urgently needed. Materials used to contain, transport, or store fluids in solar energy systems are called containment materials. Plastic containment materials are being used increasingly in solar collectors, solar ponds, tanks containing heated storage liquids, and piping. Numerous field problems have been reported with plastics. These problems stem primarily from the poor thermal and UV stability of some plastic materials. Thus, there is an overriding need for standards to be developed for nonmetallic containment materials.

Many standard methods are available to evaluate plastic materials. However, the performance requirements for containment materials in solar systems are not entirely covered by the existing test methods. The purpose of this project is to prepare draft standards for nonmetallic containment materials used in solar systems.

Initially, performance criteria, performance attributes, degradation factors and currently available tests will be identified. Tests will be assessed to determine if modifications are necessary to reflect in use solar conditions. Laboratory and field studies will be performed to obtain data needed to prepare definitive test standards. Draft standards will be prepared in conjunction with ASTM committees and submitted to ASTM for consideration as consensus standards.

Metal Containment Materials

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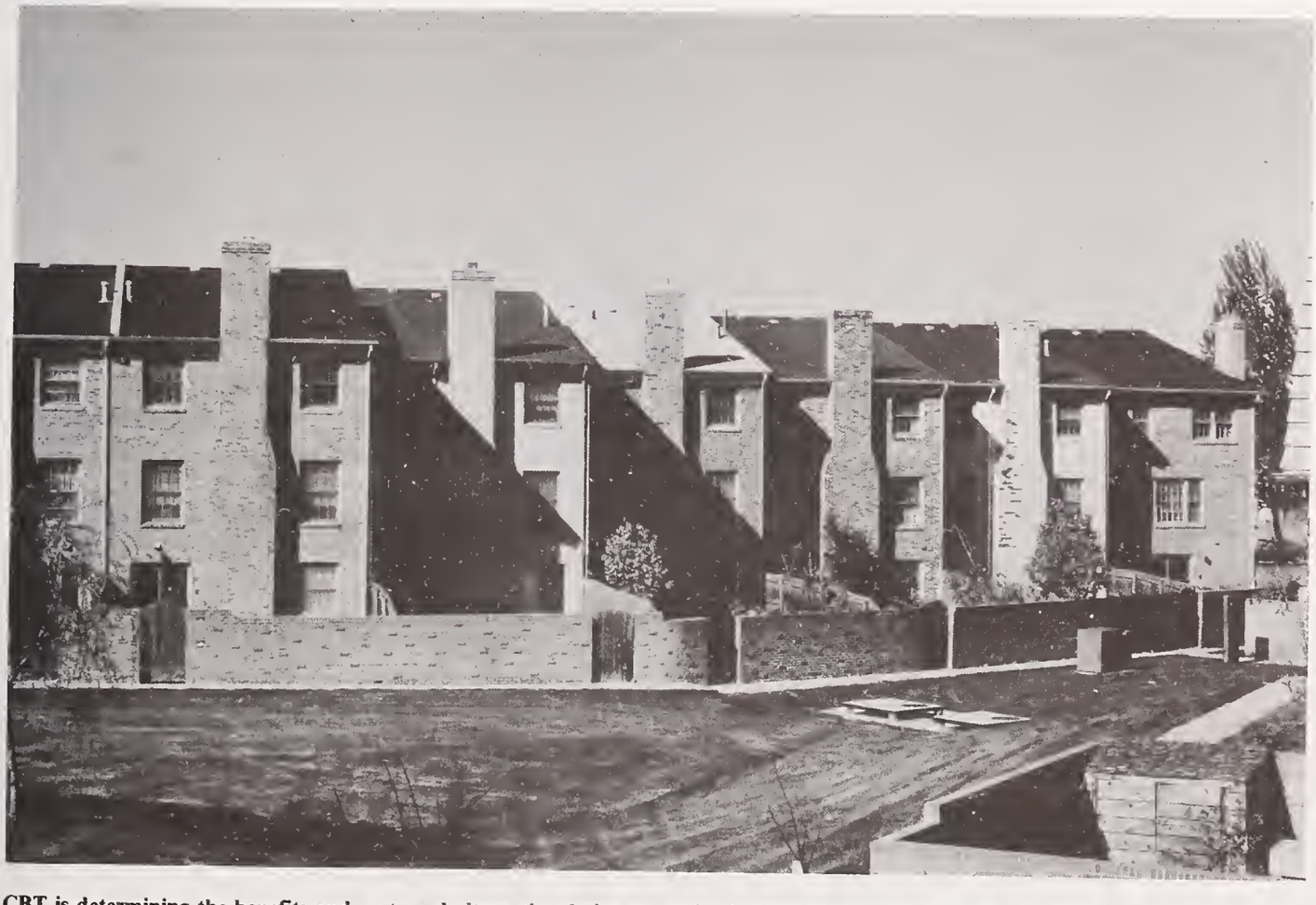
Sponsor: Department of Energy

There are no standard tests for selecting containment materials for solar heating and cooling applications. CBT is helping to fill this gap by undertaking cooperative laboratory research to determine the applicability of tests proposed by ASTM Task Group E21.10.22. The result will be an ASTM-recommended practice for metallic containment materials for use in solar heating and cooling systems.

Economics



CBT is determining the benefits and costs and alternative design strategies for insulating masonry walls in new houses.

Economic Analysis of the Manchester Building

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Sponsor: Department of Energy

The energy conservation features being field-tested in the Manchester Office Building will provide valuable technical and economic data for developing energy conservation performance standards for new buildings. The purpose of this project is to compare the life-cycle cost of the energy conserving Manchester building with the life-cycle cost of an equivalent conventional building. The approach is to develop a general life-cycle cost model, collect construction cost and operating energy cost for the Manchester building, estimate construction cost and operating energy cost of an equivalent conventional building, calculate and compare life-cycle costs of both buildings, and assess the cost-effectiveness of energy conservation measures. The research findings will help building owners and architects, engineers, and equipment manufacturers deliver more energy conserving buildings.

Economics of Masonry Walls

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Building Economics and Regulatory Technology Division

Sponsor: Department of Energy

Various groups in the building industries, as well as DOE, FHA, and HUD, are demanding better data on the thermal performance of masonry-wall construction. The masonry industry is pressing for recognition of the benefits of thermal mass, while various government agencies have been pressing for reductions in U-values of exterior walls without regard to their mass.

The primary purpose of this project is to determine the benefits and costs and alternative design strategies for insulating masonry walls in new single-family houses. The lowest-life-cycle-cost insulation applications can then be identified and the resulting thermal performance of the walls be calculated for use in establishing performance guidelines for masonry walls. These guidelines will be of considerable use to builders, the masonry industry, building researchers, and various government agencies.

The approach is to conduct a literature search to determine the accepted methods of construction of masonry walls, with and without insulation. Then we will use the NBS computer program NBSLD to determine the thermal response of these alternative wall designs and their contribution to the annual heating and cooling loads of a residence. A benefit-cost and sensitivity analysis will then determine the least-life-cycle cost designs for a range of climates and energy costs.

Techniques for Economic Evaluation

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Sponsor: National Bureau of Standards

The purpose of this project is to develop, refine, and apply methods of benefit-cost analysis in building evaluations. FY77 accomplishments included articles and reports dealing with the economics of reduced-size venting, economic impacts of building codes, economics of solar heating, and the economics of removing the lead paint hazard from buildings.

Because of the rising costs of building materials, the increasing costs of construction due to safety and environmental requirements, the rising costs of clean water, and the rising costs of fuels, the building community continues to need more sophisticated economic tools for evaluating alternative building technologies and financing mechanisms to help provide affordable buildings.

In the past, more cost-effective building designs have resulted from the use of our technical findings. Anticipated impacts are more widespread use of economic principles in building design as a result of CBT's guidelines and methods.

Design Economics for Energy Conservation

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Sponsor: National Bureau of Standards

Congressional committees, state legislatures, professional societies, government agencies, and the building industry in general are seeking information on the application of economics to energy conservation in buildings.

The purposes of this project are: to develop a practical, easy-to-use guide on design economics that can be used by architects, engineers, and other members of the design community in evaluating alternative building decisions regarding energy conservation, and to develop economic methods/design guidelines for designers and policy makers.

The approach is to send speakers to high-profile, national meetings of organizations concerned with economical energy design to describe the methods and guidelines developed by CBT; to develop a report that provides principles and guidelines to building designers for using economic approaches in evaluating energy conservation design decisions in buildings; to present to practicing architects a two-day joint course with the University of California at Berkeley on design economics, using the report as a base and testing it for applicability through classroom interaction with practicing professionals; and to develop integrated text, tables, formulas, and illustrations for a practical, easy-to-use guide.

Energy Economics for Financial Institutions

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Sponsor: Department of Energy

DOE is currently developing a demonstration program to encourage first mortgage lenders to increase mortgage limits for existing housing to finance energy conservation improvements at the time of the sale. The purpose of this project is to provide guidelines for lenders and homebuyers that can be used in determining the extent to which various conservation features, such as increased insulation, are worth investing in. These guidelines will be based on climate factors, energy costs, conservation costs, and the cost of borrowing.

The approach requires the use of an existing computer model for estimating the energy savings due to various conservation features. This energy savings data will then be used with energy cost data to determine the value of those savings relative to the cost of achieving them. This must be done for a range of energy costs, climates, and conservation costs. The end product will be guidelines for determining which retrofit items are likely to fit successfully into DOE's demonstration program.

Building Design Economics—Energy Conservation

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Sponsor: National Bureau of Standards

Energy is rapidly becoming the primary determinant of building form. Escalating energy costs and growing uncertainty about energy availability have created a whole new series of problems upon which building design decisions must be made. What is needed today are guidelines for making efficient energy conserving design decisions.

CBT's approach is to take two publications developed under the Design Economics for Energy Conservation project and convert them into a design tool. This guide will be useful to the student, but it will be directed specifically to the practicing building designer who needs a reference document for determining the economic benefits from energy conservation investments. The product will be a practical, easy-to-use guide that can be used by architects, engineers, and other members of the design community.

Cost-Estimating Factors: Residential Energy Conservation

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Sponsor: Department of Energy

Within the many Federal agencies concerned with energy conservation in buildings, a need exists for credible, consistent cost data for energy conservation features related to the design of new housing. The purpose of this project is to provide such data in an easy-to-use format, based on previous data collection by the NAHB Research Foundation. The product will be a handbook that will contain the methodology, data, and examples. The handbook will provide more consistency in government estimates of construction-related energy conservation costs and will speed up the estimation process now used in benefit-cost analysis of various conservation projects.

Solid Waste Cost-Allocation Methods

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Sponsor: Environmental Protection Agency

Currently, the municipal taxes or private fees paid by an individual household or building occupant for solid waste management services bear little relation to the actual cost of disposing of the wastes produced by that household or occupant. Generally, a fixed monthly fee or a portion of local property taxes is paid for the disposal service, regardless of either the amount of waste generated by a particular household or the actual costs imposed on the waste management system by that household. Thus, there is no incentive for those who generate solid waste even to consider the disposal costs associated with the products they use, let alone to modify their consumption patterns accordingly. A product charge is currently being discussed as one method of internalizing the disposal costs of products entering the solid waste stream.

The principal objective of this study is to evaluate alternative methods for allocating the costs of collection, transport, and disposal among the separable components of the waste stream. While most data on solid waste management systems are reported in terms of weight, it is apparent that at least some disposal costs depend on volume. Thus, major issues addressed by this research are: (1) how to convert weight data to volume data by measuring densities; and (2) how to include both weight and volumes in a cost function so as to reflect properly each characteristic's relative contribution to total disposal costs. This research is expected to provide information useful for the development of a cost-based product charge in the event such a charge is imposed.

Economics of Residential HVAC Equipment Design

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Sponsor: Department of Energy

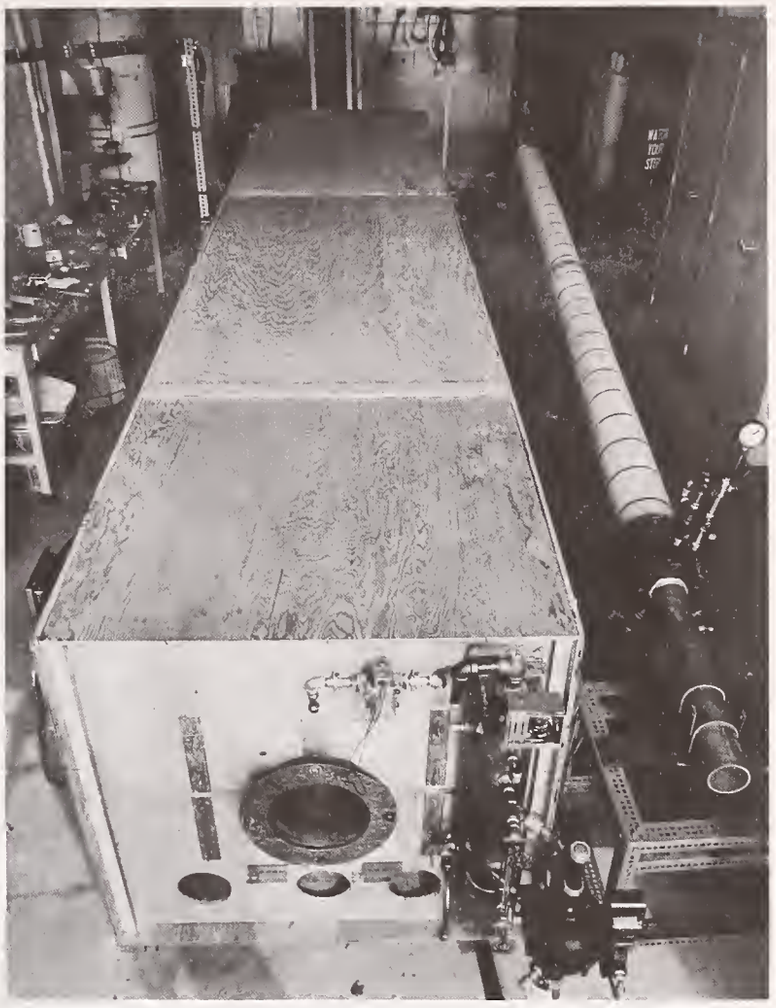
This project is in direct support of a larger NBS program, Building Energy Performance Criteria, which is intended to provide sample energy budgets for a single-family dwelling prototype. The purpose of this support project is to apply life-cycle-cost-minimization techniques to the selection of domestic heating and cooling equipment and to calculate the corresponding energy requirements of a prototype dwelling unit with known heating and cooling requirements. These heating and cooling requirements are based on NBSLD analysis of a typical detached single-family dwelling in a wide range of climates and for several levels of overall envelope integrity.

Energy conserving modifications to combustion heating equipment, heat pumps, and air conditioning equipment will be analyzed in a life-cycle cost context. Combustion equipment modifications will include an intermittent ignition device, a flue gas damper, external combustion air intake and a range of heat transfer surface areas. Modifications to heat pumps will deal primarily with variations in capacity in order to improve seasonal performance in cold regions of the U.S. Air conditioners over a range of design COP's will be examined to

determine the most economical performance level. All of these analyses will include considerations for climate, load size, energy cost and equipment costs.

The final result of this analysis will be estimates of annual energy requirements for the space heating and cooling of a prototypical single-family detached house that has been designed to minimize life-cycle energy related costs for the envelope and energy conversion devices as a combination. These estimates will be a major input into the Building Energy Performance Criteria program.

Thermal Studies



This apparatus simulates heat transfer characteristics of underground heat distribution systems. The insulated hot water test pipe at right will be inserted into a conduit, whose end is shown at the end of the box.

Thermal Measurement Technology

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Building Thermal and Service Systems Division

Sponsor: National Bureau of Standards

This project is a continuation of a several-year project in which a new type of thermal conductivity measuring apparatus and automated air leakage apparatus were developed. The former is needed for more speedy and accurate measurements of thermal conductivity for various building materials, while the latter is an important addition to the air leakage measurement capability of CBT. The existing facility for the automatic air leakage instrumentation is very bulky and difficult to transport from one test building to another.

The "Robinson" apparatus will be used to make comparative measurements of various thermal conductivity reference specimens at various temperature levels and thicknesses to validate the precision of the apparatus. A design of the new apparatus suitable for very thick specimens will be initiated during this fiscal year.

The present apparatus for the automated air infiltration meter is too bulky and difficult to handle for field operation. A new design for the unit will be made to carry it in several pieces.

A report describing operating experience and calibration accuracy will be prepared on the new "Robinson" apparatus. The instruments being developed under this project are critical to the energy conservation of buildings.

Thermal Performance of Major Building Elements

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Center for Building Technology
Headquarters

Sponsor: Department of Energy

This program will be carried out through a comprehensive plan developed in cooperation with the DOE, BRAB, and the building material and component industries. The following major elements are involved: a testing program in industry laboratories to generate a data bank on current and innovative building envelope systems; research at NBS, ORNL, LBL, and elsewhere to develop new guidelines on control of heat transmission, air leakage, and moisture transfer in major building elements and whole structures, to characterize heat transmission in attics, crawl spaces, slab-on-grade construction, and massive building elements; laboratory and field research to integrate the benefits of daylighting, solar effects, and thermal resistance of windows and skylights; new measurement technology and test procedures to standardize the methodology for characterizing building element performance; and development of analytical models for predicting the thermal performance of composite building elements to minimize large-scale testing. The results from this activity will be greater and more predictable energy conservation, a sound basis for competition in the building industry, and greater assurance of building durability, habitability, and economy to the consumer.

Attic Ventilation Criteria

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Building Thermal and Service Systems Division

Sponsor: Department of Energy

This study will determine the kinds of moisture-related problems found in attics and the extent to which these problems are due to the type and amount of thermal insulation used in attic spaces.

The FHA/HUD Minimum Property Standards provide guidelines for the minimum amount of attic ventilation to prevent moisture damage. These guidelines were derived from limited data on attics with limited amounts of ceiling insulation. Today, a strong need exists to marshall information on the moisture question with respect to attics having large amounts of ceiling insulation.

The approach for this project is to search the literature and organize findings in a compendium, to survey experts in the subject area, and to go into the field and examine firsthand the moisture content of attics that are heavily insulated. A report will detail the results of this research. This report will compliment the document to be published in late FY 78 on attic ventilation measurements in Houston, Texas.

Natural Ventilation for Home Cooling

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Building Thermal and Services Systems Division

Sponsor: National Bureau of Standards

This project will determine when outside air may be substituted for air conditioning, what ventilation rates are required, and how much energy is saved. It will also develop algorithms to simulate the effects of natural ventilation under different ventilation schedules and different climatic conditions.

Cooling rate measurements will be made in a home under different rates of ventilation and quantify the conductive and convective components of heat loss. It is further proposed to quantify the effect of closing a house during the day and opening it at night during different rates of ventilation. Tracer measurement of infiltration rates at high rates of air exchange will be explored. A mathematical model of natural ventilation will be developed. It is also hoped to develop methods for measuring natural cooling of a house in the outdoor environment and correlate it with on-site weather data. Also included in this research is the pulsed air leakage through cracks due to atmospheric turbulence, and the development of methods for constant monitoring of air leakage by sensitive pressure transducers.

The project will be coordinated with several other ventilation projects that deal with attic ventilation, whole-house fans, and ventilation controls. This research is also being funded by DOE and with the Lawrence Berkeley Laboratory.

Latent Cooling Performance of a Fan-Coil Unit

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Sponsor: Department of Defense Tri-Services Committee

Fan-coil units are installed in many military dormitories and other types of buildings. When these buildings are located in high humidity regions, they simply do not remove enough moisture from those spaces, resulting in mildew and fungus growth. This report will test a fan-coil unit by varying its control schemes, air flow rates, and other parameters in environmental chambers to evaluate its sensible and latent cooling performance. Tests are conducted for both steady-state conditions and in saturated rooms.

This study will result in a report on the test results and the recommended fan-coil unit system modifications to improve dehumidification capacity. The sponsor intends to use the results for design and specification criteria for existing and new barracks. In addition, the knowledge gained from this research should allow CBT to recommend changes in the existing ASHRAE standard on fan-coil units.

Underground Heat Distribution Systems

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Sponsor: Department of Defense Tri-Services Committee

Although numerous underground heat distribution systems are on the market, only the air-conduit systems are approved for Class A (high water table) application by the Tri-Services. There are, however, several non-air-conduit systems that appear to be acceptable for Class A application. Critical evaluation and testing are required to determine the suitability of these new systems. At the request of the Tri-Services, CBT will acquire new underground systems and develop suitable test procedures to determine the adequacy of these new systems for Class A application. Also required are several field visits to observe the *in-situ* performance of these systems.

In the past, CBT has been considered the central source for technical information on underground heat distribution systems and is frequently consulted by other government agencies and industries.

Effects of Moisture in Retrofit Insulation

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Structures and Materials Division

Sponsor: National Bureau of Standards

Large increases in the use of thermal insulation in buildings will be required by the national energy policy. However, there are serious questions about the accumulation of moisture in insulation and its effects on the efficiency of the insulation and on the permanence of the flame retardants used in some of them.

In this project, the absorption isotherms of common insulation for buildings will be determined, as will the rates of transfer of water vapor into insulation under different relative humidity, temperature, and total pressure conditions. The effects of differences in composition within a class of insulation on moisture absorption will be investigated. Movements of water-soluble constituents of insulation under temperature and RH gradients, including ones in which condensation

occurs, will also be investigated. The results of the work will be reported and guidelines for the selection of insulation will be presented.

The results will be published in the open literature and talks will be presented at conferences such as those conducted by ASTM and ASHRAE. The improved guidelines and criteria will aid the selection of cost-effective insulations. Knowledge of the permanency of flame retardant treatments of insulations will help reduce the risks of fire.

Large-Scale Test Facility for Insulated Building Elements

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Sponsor: National Bureau of Standards

This project will develop several conceptual designs of a large-scale test facility for insulated building elements such as walls, ceilings, floors, wall/ceiling joints, and wall/floor joints under laboratory-controlled environmental conditions.

Although the existing test facility for air-moisture and heat transfer through building walls serves as an evaluation of a wall section in terms of heat conduction, moisture penetration, and condensation, it is inadequate for the comprehensive studies of joints between the roof and wall and between the floor and wall, where crucial air leakage, condensation, and the cold bridge effect (thermal short circuit) take place.

In coordination with the ASTM C-16 committee, ASHRAE TC committee on thermal insulation, industrial research laboratories such as Owens/Corning, Johns Manville, and with the Federal Construction Council, BRAB/TAU group, several large-scale design concepts for test facilities will be developed and evaluated during the fiscal year with respect to feasibility, accuracy, application, and cost. Included in the studies will be the instrumentation and material handling aspects and automated data acquisition. The facility, when completed, is expected to make a large impact on energy conservation standards such as ASHRAE 90-75, HUD Minimum Property Standards, and the NCSBCS Model Code, as well as on ASTM C-236.

Air and Smoke Migration in Building

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Sponsor: National Bureau of Standards

It is important to predict the movement of smoke and hot air within a building through doors, cracks, elevator shafts, and ventilation systems. Aiding this work will be a number of computational techniques that have been used to predict the distribution of heating and cooling air. The Center for Fire Research at NBS has been developing a sophisticated computer program to predict smoke migration under simulated fire conditions. This program will be modified to include normal heat transfer processes within a room under non-fire conditions for use in predicting air motion and

temperature. A modified computer program, a user's manual, and a technical report summarizing work will be produced.

The program will be carried out jointly by CBT and the Center for Fire Research. Both Centers will select technical personnel to oversee and use the improved computer program. The computer program should be able to generate a technical data base for the modification of current energy conservation standards and design practices, which do not now consider the spatial distribution of air and temperature. The impact on the building community will be the availability of a very comprehensive analytical tool to study the multi-room energy transfer problem.

Thermally Efficient Roofing Systems

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Sponsor: Department of Energy

The nation's inventory of low-slope roofing is approximately 25 billion square feet and the average thermal resistance (R) of these roofs is less than 7. Over 40 percent of the low-slope roofs contain no insulation at all. The magnitude of the energy savings that could be realized by an increase of 10 in the thermal resistance of the nation's 25 billion square feet of low-slope roofing in commercial/industrial buildings in a 5000 degree-day climate could result in a savings of 155,000 barrels per day equivalent. Conversely, during a cooling season, a potential energy savings of 700 million kilowatt hours or $15.4 million could be achieved in a climate requiring 1,000 equivalent operating hours.

Other serious problems associated with roofing are the performance of roof systems containing increased amounts of insulation and the effect of moisture on the components in the system. Small amounts of moisture in some insulations will significantly reduce thermal efficiency. Moisture in roof systems has also led to premature membrane failures such as blistering, splitting, ridging, and wrinkling.

This project is a cooperative effort with industry, the private sectors and government. The objective is to develop and provide the technical basis for increasing the thermal efficiency of new and existing low-slope (industrial type) roofing systems while retaining essential characteristics of serviceability of the total roof system and durability of the roofing membrane.

Under this project, CBT will take the lead in supplying the building industry including ASTM with criteria and guidelines for increasing the thermal efficiency of roofing systems. Together, these should result in the selection of effective and compatible materials for serviceable and durable roofing systems and in enormous energy savings.

Thermal Insulation, ASTM C-16

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Sponsor: National Bureau of Standards

The efficient use of thermal insulation has become the first line of defense against fuel wastage. ASTM and Federal standards are widely used to implement incentives and requirements contained in legislative and building codes and standards, for both new and existing buildings of all types. For this reason, CBT takes an important part in the task of generating, maintaining, and up-dating methods of test and material and performance specifications sponsored by ASTM. CBT contributes by direct participation at committee meetings and by preparation of written materials and analyses between meetings on a year-round basis.

Dow Chemical Research Associate Program

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Sponsor: National Bureau of Standards

In line with CBT's efforts to develop evaluation criteria for mobile homes, the nation's largest group of low-cost housing units, Dow Chemical Company provides a research associate to work with CBT engineers for testing its innovative mobile home prototype in the NBS environmental chamber. The evaluation entails the use of a sandwich panel, cladded with fire-retardant gypsum interior finish board. The environment chamber tests include heat loss, heat gain, air infiltration, thermographic study of wall heat leakage, and energy consumption. Similar tests have been conducted in previous years on a conventional mobile home (fiberglass insulation between the wooden studs). The results of these two systems will be compared to see how effective the Dow sandwich panel design is from the standpoint of energy consumption and air leakage. The findings of this program will be made available to the public. They are also expected to impact the mobile home codes such as NFPA 501B (ANSI A119.9).

Building Infiltration Evaluation

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Sponsor: Department of Energy

Reduction of outside air is one of the strategies proposed to save energy in the heating and cooling of buildings. There is need for better information on natural ventilation rates of buildings with outside air dampers closed. High-rise buildings present special problems. Such information is needed before we know where we stand with respect to existing ventilation standards, as well as the possible revision of standards.

Milestones for the current year will focus on the measurement of the effect of wind and temperature effects on the natural air leakage rate of the NBS Administration Building. A computation scheme recently developed at the National Research Council of Canada for predicting air infiltration rates in tall buildings will be experimentally tested. If successful, the results will provide strengthened methodology for predicting the natural ventilation rates of high-rise buildings.

Thermal Modeling of Slab-on-grade Floors

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Sponsor: National Bureau of Standards

This project will improve existing handbook data on ground-floor heat loss for slab-on-grade floors by conducting numerical calculations of heat conduction equations. Steady and non-steady finite difference equations are being solved to develop a model that simulates the heat transfer of slab-on-grade floor.

Mechanical Systems

Drs. Walter Parken (left) and George Kelly, Building Thermal and Service Systems Division, monitor the performance of a residential heat pump in one of CBT's environmental laboratories.

ASHRAE Standards for Heating and Cooling Equipment (Heating)

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Sponsor: National Bureau of Standards

Currently, testing and rating requirements for central furnaces and boilers are described in a number of standards, including ANSI Z21.47-1973 and ANSI Z91.1-1972 for gas and oil-fired furnaces, ARI 280 for electric furnaces and boilers, ANSI Z21.13-1974 for gas-fired low-pressure boilers, and the Hydronic Institute's "Testing and Rating Standard for Cast Iron and Steel Heating Boilers" for oil-fired central heating boilers. These standards all require a steady-state performance test and do not account for any part-load or seasonal performance. To estimate the seasonal efficiency and annual operating cost of fossil fuel heating systems, it is necessary to account for the various heating system losses under cyclic operating conditions and for the effect of combustion and draft control air on infiltration.

The state-of-the-art in our industry has now reached the point that we are capable of determining a more realistic estimate of the true annual cost of operation. Under this project, CBT will help ASHRAE develop a standard testing and rating procedure that will enable a manufacturer to determine the seasonal performance of any central furnace or boiler (gas, oil, electric) with an input rating $\leqslant$420,000 Btu/hr.

ASHRAE Standards for Heating and Cooling Equipment (Air Conditioning)

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Sponsor: National Bureau of Standards

Testing and rating requirements for unitary air conditioners are described in the ARI Standard 210-75 and for heat pumps in the ARI Standard 240-75. Test procedures used to evaluate them are given in ASHRAE Standard 37-69. However, since these procedures are based on steady-state tests at only one rating point, estimating the cost of operation of an appliance in a given climate is not very realistic. The state-of-the-art of our industry has now reached a point where we are capable of determining for any climate the seasonal performance of an appliance using either steady-state or cyclic tests, the latter offering more accurate results but at a cost of more involved testing. The Federal government under its Appliance Labeling Section of PL 63-194 has already proposed a part-load test and seasonal performance rating procedure for residential central air conditioners.

Under this study, CBT will help ASHRAE develop a standard testing and rating procedure that will enable a manufacturer to determine the seasonal performance of any central air conditioner (single phase, air cooled condenser) that has less than 65000 Btu/hr output. This standard is the ASHRAE Standard 103.1P Method of Testing for Cooling Seasonal Efficiency of Unitary Air Conditioners and Heat Pumps.

Performance Prediction Modeling for Heat Pumps and Air Conditioners

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Sponsor: National Bureau of Standards

The objective of this project is to develop a theoretical simulation model for predicting the dynamic performance of a unitary heat pump or air conditioner. The product of this project will be a model, similar to the NBS furnace/boiler model, which will act as the backbone for our empirical program of predicting energy performance of all heat pumps and air conditioners of residential size.

The results of this project as well as the laboratory projects under DOE/FEA sponsorship are to be implemented through the ASHRAE Standards Committee 103, under which round robins and data exchanges are to be conducted to develop a simplified, less costly dynamic rating procedure.

Development of Standard Test and Rating Procedure for Heat Pump Systems—Modified Temperature Bin Method

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Sponsor: Department of Energy

The BLAST computer program will be used to model and predict hourly residential heating and cooling loads. Several residential constructions will be modeled and hourly heating and cooling loads predicted in several regions around the country using actual weather data. From the hourly load data, a correlation will be developed to predict the building heating and cooling loads. The correlation will then be used to develop a modified temperature bin procedure which calculates the heating and cooling seasonal efficiency and seasonal energy consumption. This manual calculation procedure will be compared with more exact methods using computerized hour-by-hour analysis.

A modified temperature bin calculation procedure will be developed which predicts the building heating and cooling load, as well as seasonal energy usage and seasonal efficiency, more accurately than the present method. The calculation procedure will purposely be kept simple, not requiring the use of a computer. A permanent data file will be available containing hourly cooling load data for several residential models in several regions throughout the country, using actual weather data. This data file may be used by building researchers in the future for building heating and cooling load analyses.

Development of Standard Test and Rating Procedure for Heat Pump Systems—Test Method for Engine-Driven Heat Pump

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Sponsor: Department of Energy

With the sponsorship of DOE, a number of innovative heat pump systems are currently under development around the country, including heat engine-driven heat pumps. There is, however, no standardized test and evaluation procedure available for these innovative systems. Industry and Government are unable to evaluate and compare these new heat pump systems and to make sound decisions regarding which are worthy of further development. A standardized test and rating procedure, incorporating provisions specifically tailored to the nature of each innovative system, is required so

that the published results of different research teams working on different types of heat pump systems may be effectively compared on the same technical basis. The objective of this particular project is the development of a generic test and rating procedure for engine-driven heat pumps.

The initial phase of the study will be a survey and review of experimental and analytical results obtained on engine-driven Rankine cycle heat pumps by other researcher agencies. The survey will not be restricted to a particular type of engine, but rather, will include a range of heat engines (Stirling cycle, Diesel cycle, Rankine cycle, Brayton cycle, etc.) which are potentially suitable for heat pump applications. This information will then be integrated with: a) NBS experience and test results on Stirling cycle engine and diesel engine driven heat pumps, b) existing NBS test and rating procedures on electric driven Rankine cycle heat pumps and other heating and cooling devices, and c) appropriate ASME-SAE-ASHRAE test and rating codes. It is expected that this approach will result in the draft of a comprehensive test and rating procedure sufficiently general that it may be used for most of the engine driven systems likely to be employed in building in the near future.

Furnace Efficiency

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Sponsor: National Bureau of Standards

Based on our extensive fieldwork in residential oil burners, we have concluded that the major obstacle to improving operational efficiency is that servicemen do not take the necessary time to perform tune-ups accurately. The basic measurements required are on smoke, flue temperature, and CO_2 in the exhaust. The present field test requires approximately 30 minutes. This project will develop a meter system to measure the three parameters with equal accuracy in less than 10 minutes. The prototype will be made available to manufacturers for development. The two innovations in the new meter are continuous gas flow absorption and a method for predicting steady-state temperature based on warm-up temperature readings.

After a thorough review of possible CO_2 detection methods, the continuous-flow ORSAT technique has been selected and is under development. In the end, this device will facilitate the adoption of CBT's furnace tune-up procedure because it will shorten the tune-up time. At least one major meter manufacturing firm has agreed to undertake mass production if feasibility is proven.

Part-Load Efficiency

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Sponsor: Department of Energy

Considerable energy waste is known to result from mismatching and oversizing (safety-factor padding) of mechanical equipment in large HVAC systems. This practice has come about, in part, because of the lack of published data describing the part-load and/or dynamic-load characteristics of the equipment.

The role of CBT will be one of the central coordinator of all major equipment part-load data. This role entails determination of equipment priorities, the type of data needed, and the method by which the data will be gathered; designation of who should gather specific data; and development of the format in which the data should be presented. It is anticipated the format will take either an algorithmic expression for computer program subroutine or a design book for manual calculations. The methods of data generation could include searching and transcribing from existing literature, theoretical modeling, laboratory or factory experiment, and field evaluation.

The overall (3 years) plan has been developed: generally with details filled in as the project proceeds. It amounts to a listing of the major equipment items and a determination of the status of part-load performance data. If the data are known, the best source of information is determined. If data are unknown, the best method of generating the data is determined. The output of the project will take on forms which will be useful for either computer or manual design calculation schemes.

Automated HVAC Controls

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Sponsor: National Bureau of Standards

Automated heating, ventilating, and air-conditioning systems can control building comfort, energy use, fire alarms, security alarms, maintenance alarms, and several other functions. Their application has greatly increased since the energy cost increase of 1973. Even though all the systems supplied by different manufacturers use the same basic components, different techniques in system design and application make the selection of the most effective system quite complex. For this reason, CBT is studying system performance and developing a purchase specification for consumers.

Based on prior experience with building energy conservation, a performance criteria and specification will be drafted. Topics will include ease of control, system reliability, future expandability, maintenance and serviceability, flexibility in software/hardware program changes and costs.

Appliance Energy Usage

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Sponsor: Department of Energy

The Energy Policy and Conservation Act of 1975 requires that CBT assist the Department of Energy in developing test procedures for certain products. CBT is helping to meet this obligation by developing test procedures for furnaces, boilers, heat pumps, and central air conditioners. DOE will use this procedure in deciding the final test procedures that manufacturers will be required to use in labeling their products.

Laboratory testing and computer modeling is being carried out to develop and verify the test and calculation procedures for furnaces, boilers, heat pumps and central air conditioners. Close contact is being maintained with various manufacturers and standard-writing organizations to assure the accuracy, fairness and acceptability of the test procedures.

The project will result in three reports containing the test and calculation procedures for furnaces/boilers, heat pumps, and central air conditioners. Several technical publications on the topics of seasonal efficiency, annual operating costs, expected energy savings resulting from different design options, will also be published. This work will result in labeling furnaces, boilers, heat pumps, and central air conditioners with accurate estimates of their seasonal performance and annual operating cost. Consumers then can select the most efficient appliance and thereby help conserve our energy resources.

Household Energy Usage

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Sponsor: National Bureau of Standards

This project provides data on the actual usage of major household appliances, the energy efficiency of the appliances, the environment in which the appliances operate, and the user habits that affect their operation. A series of data tapes obtained from a group of twelve townhouses over a period of two years will be analyzed to obtain actual performance of water heaters, refrigerators, dishwashers, clothes washers, clothes driers, ranges, central furnaces, and central air conditioners. This analysis will be used to help verify laboratory test methods for evaluating household appliances for their energy efficiency and water usage. This work helps establish minimum energy and water-usage standards for household appliances.

Plumbing

Shower heads are being tested to determine their water conserving potential.

VA Hospital Plumbing Criteria

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Sponsor: Veterans Administration

In this project, full-scale vent stack and header test configurations will be instrumented in the Plumbing Research Laboratory with high speed data acquisition components coupled to CBT minicomputer. Dynamic measurements of pneumatic parameters will provide reduced-size venting (RSV) and vent header design data. Larger header bend configurations will be tested to determine limit design conditions of flow circulation exchange, pressure losses, and friction drop. The result of this will be methods for measurement and control of RSV/Header Testing. Data will be collected and analyzed for design and recommendation reports to the VA on variable RSV, vent header limits, vent header return bends and mechanical vents. The results will also be made available to the model code groups and to the ANSI A40 Committee for National Plumbing Code Revision. Selected portions will be prepared as technical papers to the American Society of Plumbing Engineers and journals. Overall, incorporation of RSV systems in Veterans Administration hospitals could result in large cost savings within two years.

Field Evaluation of Reduced Size Venting

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Sponsor: Department of Defense, Tri-Services Committee

To date, data on reduced-size venting evaluations have been broadly useful to CBT as a basis for initiating an information library useful in updating the water demand design curve, i.e., "Hunter's Curve." The results of our numerous RSV tests have been presented in several NBS reports and talks to a variety of audiences including the ANSI A40 Committee and NCSBCS.

Overall, the success of this project has not been limited to showing the effectiveness of RSV. It has demonstrated how innovative approaches can gain recognition and how the performance-oriented approach can lead to materials and energy savings.

National Plumbing Code, ANSI A40

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Sponsor: National Bureau of Standards

The ANSI A40 National Plumbing Code was last revised in 1955; later efforts to update it were unsuccessful. The current revision of the Specification Code is anticipated to have impact on model codes and now has possibility of gaining ANSI acceptance. The Performance Code is being developed as complementary to the revised code and is independently beginning to be developed; the effect on other codes is expected to be significant.

CBT will prepare inputs for developing revisions to the ANSI A40 code. CBT will also provide technical inputs to selected guidelines; develop recommended language and statements of chapters; supply commentary in reviews of final revised code and ballot on completed document.

CBT contributes by direct participation and by presenting written materials to the various subcommittee

chapter leaders of the revised code. The delivery of performance recommendations occurs at meetings between CBT staff and model code officials and at professional and trade associations, and through papers prepared for USNCCIB-W62, CIB-W62, ASPE, ASSE, and NCSBCS. The documents provided by CBT have considerable influence on the shaping of the Code. The constituency affected by these CBT inputs includes design engineers, local inspectors, and elements of Federal specifications.

Plumbing Systems Design Criteria

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Sponsor: National Bureau of Standards

CBT is a primary source of national research in plumbing. The acceptance of innovative engineering solutions to problems requires improvement in method, development of guideline criteria, and design requirements based upon a substantial data base. The plumbing community has identified the need for revision of storm drainage systems requirements from new weather load data information. Further, the support of Veterans Administration Hospital plumbing systems studies is derived from the Plumbing Research Laboratory dynamic measurement capability. The study of the dynamics of reduced size venting for the V.A. "building system" requires adaptation of the existing laboratory, data acquisition, and minicomputer programs for that test program. Likewise, other studies support the CBT advocacy and participation in the thrust to develop an ANSI A40 Performance Based National Plumbing Code as a national consensus standard.

Technology of Water Conservation

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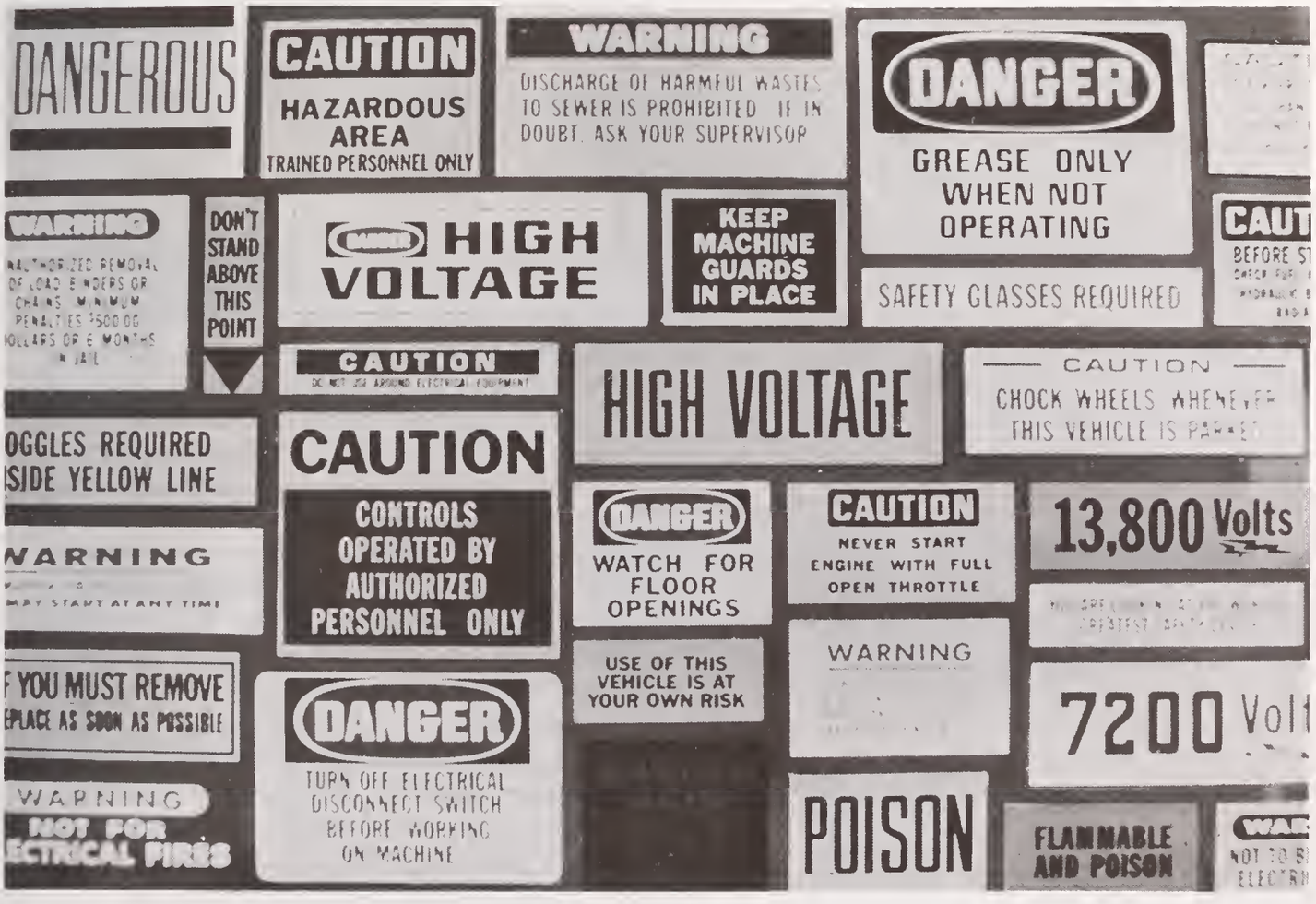
Sponsor: National Bureau of Standards

Although water shortages are being experienced across the United States, present sources of water and existing treatment plants could remain adequate for a number of years if reduction in potable water usage could be achieved. However, this will require a great deal of CBT research, especially in determining the effect on domestic water use of new flow-rate standards that mandate flow reduction devices, the effect on hygiene and waste transports due to reduction in toilet flush water, the energy savings from reduction in hot water usage, and the minimum potable water requirements for residences. As a first step, CBT is developing test procedures for evaluating water conserving toilets, and methods for evaluating the effect of reduced flow on the transport of solids in horizontal drainage systems.

This research will provide technical bases for changes in codes and standards for water consuming devices. Also, planning officials, including professional societies, model code groups, and the ANSI A40 Committee, will be provided with technical findings to serve as a water usage resource base.

Environmental Design



Warnings and other safety-related information are frequently communicated through visual displays. CBT researchers are studying the color and legend requirements for these signs.

Building Access/Egress Studies

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Sponsor: National Bureau of Standards

The U.S. has a very high incidence of injury and death due to fire. One of the critical aspects of these tragic losses is pedestrian egress and escape movements during an emergency. To predict how people will react during an emergency, we must have a solid base of information as to what they do during normal operations.

During the sixteen days of the 1976 Summer Games in Montreal, time samples of crowd flow along the major circulation routes within the stadium were collected using super-8 film and videotape. From these data, measures of flow and queue formation at key points throughout the movement system will be made. From working drawings of the stadium and from detailed plans, the physical route dimensions, configurations, and information delivery systems can be determined. By linking these environmental factors with the data on observed pedestrian flows, the impact of the former on the latter can be determined.

Because of the relationship between a study of pedestrian movement and earlier projects on door and stair use, unpublished technical and consumer reports from these projects will be available. The result will be a complete archive on doors, stairs, and circulation.

The major benefit of this study will be the identification of those features of complex circulation systems that regulate flow throughout the remainder of the system. The identification of such "control points" or "choice points" will be useful in designing and assessing the effectiveness of large pedestrian movement systems such as those found in large transportation facilities and those designed for emergency egress from places of assembly.

Building Access/Egress Research Planning

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Sponsor: National Bureau of Standards

Codes and standards relating to building access and egress are based almost entirely upon engineering principles. Accordingly, they appear to be blind to considerations for human behavioral and psychological factors believed to influence effective egress and access. This gap is believed to be especially acute where occupants suffer from mobility, perceptual, and/or developmental disabilities. Moreover, such research has suggested that the behavioral science state-of-art related to building access and egress provides no data base sufficiently adequate for the preparation of specific performance criteria of regulatory statements. Consequently, the research program developed through this project shall address the long-range objective of providing the building community with supportable technical bases for complex and multifaceted design decisions. The special problems covered under this broad objective include emergency egress by normal building occupants, as well as access and egress by handicapped persons under both emergency and non-emergency conditions. The

development of a comprehensive technical base for design criteria implies a multidisciplinary approach, involving architectural, behavioral science, and engineering expertise.

Simulation of Human Behavior in Fires

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Sponsor: Public Health Service, Department of Health, Eduation and Welfare

A computer program that simulates human behavior in building fires was prepared. The long-range objective of this simulation is to provide a tool with which building designers and code administrators could better assess the life safety potential of both planned and existing structures. The immediate purpose of the study has been to explicate the emergency egress phenomenon, and to identify areas where new empirical investigation will be required. This project addresses itself to the completion of the computer programming effort already under way, and to the conduct of simulation studies aimed at providing data useful to the calibration and validation of the simulation program.

Manchester Building—User Acceptance

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Sponsor: Department of Energy

The Manchester energy conservation demonstration building has several innovative design features. But it is essential to determine how these innovations compare with one another, not only in energy costs but in terms of occupant acceptability and performance. Occupant reactions to the environment are not only general and long term, but also are highly specific and time dependent—i.e., they change within a single day. Two approaches will be employed—one based on questionnaire surveys and the other on an automated system that permits responses by pressing a button, thus allowing reactions to be collected and yet not disrupt the working activities of the employee. Emphasis will be concentrated on the thermal and luminous environment and windows.

One of the major innovations of the building is the use of smaller windows as a means of conserving energy. This design characteristic is controversial—especially since very little is known concerning the effects of reducing window size on building occupants. The building includes five different luminaire systems, having approximately the same power, but with probable differences in the effectiveness of the system for visual performance. A series of CBT reports covering all these matters will detail how these occupants are responding to these latest energy conservation schemes.

Noise in and Around Buildings

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Sponsor: National Bureau of Standards

The objective of the project is to develop improved procedures for measuring and characterizing environmental noise in buildings in terms that are relevant to human responses. In turn, these will become the basis for equitable regulation of noise and of isolation against environmental noise. Noise abatement and control ultimately rests upon the ability to describe the effects on people of a given noise accurately and precisely. Architects, engineers, and builders seek reliable criteria and means for analyzing and controlling noise propagation within and into buildings. However, measurement procedures are often not standardized because, there are no agreed-upon noise criteria.

Human response to noise is partially dependent upon three parameters: amplitude, frequency spectrum, and the variations of both of these quantities with time. To provide a complete description of the noise environment requires a combination of these three parameters, using a conversion scheme. The result is a psychophysical scale and algorithm that relates the important noise parameters to a subjective response that cannot be measured directly. Work in that direction is continuing at the Center.

Noise Control for Designers

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Environmental Design Research Division

Sponsor: National Bureau of Standards

Adverse noise effects are increasing, and they are most pronounced in urban settings. The Environmental Protection Agency estimates that 10 million people live in environments whose sound level is seventy decibels or more. The objective of this project is to provide architects, engineers, and planners with improved knowledge of acoustic characteristics and sound attenuation techniques as a base for better design practice. The project will produce an audio visual presentation that realistically reproduces sounds commonly found at or near building sites and sounds generated within buildings, while simultaneously showing the source of sound and the sound's acoustic profile. In this way the audience will come to understand numbers, graphs, and sounds in a linked fashion. These base sounds will then be attenuated or reduced by architectural modification of the physical environment, and the resulting sounds, numbers, and graphs will be presented for comparison. Alternative attenuation techniques will be demonstrated and methods of calculation and prediction will be presented by means of selected references to NBS publications.

Highway Noise Criteria

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Sponsor: Department of Transportation

Noise from highways and urban traffic has been shown in social surveys to be a major source of annoyance to the public. Research is underway to develop improved criteria for rating time-varying highway noise. Recordings of real and simulated traffic noise have been obtained in the field. These recordings are being analyzed for representative stimuli to be used in laboratory psychoacoustic studies. Laboratories use four different psychoacoustic procedures to ascertain human response to time-varying noise. The data thus obtained will be evaluated in terms of several conceptual models of human response, in conjunction with previously reported data, to develop practical and relevant highway noise criteria.

The data obtained will be made available to voluntary standards organizations such as ANSI and ASTM and are likely to result in the development of new voluntary standards. These data will be useful in developing criteria for building envelope design, building site analysis, and in making decisions for the retrofit of existing buildings to reduce highway noise.

Color and Appearance

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Sponsor: National Bureau of Standards

The long-range objective of this project is the continued development and application of color science and technology with the aim of optimizing the use of color in the promotion of safety, communication, visual performance and comfort, and esthetic satisfaction. Current emphasis is directed toward safety.

The tasks undertaken as part of this project tend to divide into the categories of surface color and illumination color. The surface-color part concerns itself primarily with color standards, color-order systems, and the dissemination of color information to those concerned with specific applications. The principal accomplishments last year were facilitating and adoption of ANSI Z53.1, Safety Color Code for Marking Physical Hazards, and publication of NBS Spec. Pub. 440, *Color: Universal Language and Color Names.*

The illumination-color part will now be expanding its research activity, with the completion of the Color Applications Laboratory. This equipment will be used for scaling-type studies of the visibility of warning lights. The idea is to permit any signal light to be given a numerical rating on a common, standardized scale that represents people's reactions. A standard reference light will be developed, to which all other lights will be compared. Then, the quantitative effects on conspicuity of intensity and flash rate will be studied, and a paper describing the scaling methodology will be published.

In addition, a seminar on Color in the Building Industry will be convened, to determine the most pressing color problems.

Building Illumination Standards

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Sponsor: National Bureau of Standards

The building illumination community is engaged in a major controversy over the optimum design of lighting systems versus the national need to conserve energy. The basis for recommended illumination levels is being seriously challenged, and often rejected, by practitioners in the field, but no sound method is available to replace it. A key element required is the provision of precise physical measurement techniques to provide the foundation for vision research, guide systems design, and evaluate effectiveness of installed systems.

To this end, CBT is developing a laboratory capable of precise physical measurements under both laboratory and field conditions. The result will be a more precise way of measuring bi-directional reflectance for a variety of standard tasks. Eventually, the research should lead us away from today's wasteful habit of requiring more light in buildings than is actually needed to complete simple tasks.

Visual Environment

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Sponsor: National Bureau of Standards

The first part of this project deals with establishing an empirical basis for recommending levels of illumination for visual task performance. The study recognizes that two lighting systems flooding the same task surface with identical levels of luminuous flux can differ significantly in the effectiveness of the light for task performance. The difference is dependent on the placement and design of the luminaires. To study these areas, work is proceeding on developing a reference lighting system from which the relative performance of lighting systems can be obtained, a standard task that is representative of commonly encountered tasks, and instrumentation to measure contrast rendition. Researchers are also looking into some of the basic concepts involved in the prediction of contrast. To this end a program to simplify calculation and understand contrast rendition has begun.

Visual Alerting

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Sponsor: National Bureau of Standards

Visual alerting is an essential element in the safe and effective use of buildings, grounds, and facilities—largely through color coding, signs, signals, symbols, and other marking codes. But for these mechanisms to be complete and effective, uniformity is essential. Industry, government, standards organizations, building designers and users, and the general public must use alerting systems that are both clear and consistent. The proliferation of alerting systems can degrade safety and building effectiveness.

The central ANSI Visual Alerting Secretariat, administered by CBT, encourages a nationally unified system of color, signs, and symbols in American National Standards and assists in the development of international standards by participating in the International Standards

Organization (ISO). Among the direct responsibilities of VASEC is to administer the administrative requirements of ANSI Committee Z535, including respective subcommittees for safety colors, safety signs, and symbols.

Criteria for Signs in Workplaces

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Sponsor: Occupational Safety and Health Administration

Warnings and other safety-related information are frequently communicated through visual displays, both within fixed workplaces and around temporary work sites, indoors and outdoors. Safety-related visual displays are usually intended to serve two functions: alerting personnel to the presence of some situation requiring attention; and transmitting further information concerning the nature of the special situation and/or the action to be taken by the viewer. In relation to such signs, there is a growing proliferation of requirements at the international, Federal, and state levels addressing aspects of color or legend. And in general, there is a lack of experimental research to support the criteria for these requirements. Moreover, there are no formalized procedures for measuring compliance with the requirements.

This project will address these problems through literature searches, as well as laboratory experiments. Results from this research will bring OSHA's current standards on signs into agreement with the latest research findings and with national and international agreements moving towards a universal set of conventions for visual displays.

Task Lighting Criteria

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Sponsor: Department of Energy

There are designers who question the validity of the current North American recommendations for levels of illumination. Studies done at CBT indicate that the experimental basis for the current determination may be invalid for many of the tasks encountered in practice. Preliminary studies conducted with gratings at CBT indicate that when visual performance is measured by equality of contrast, the function obtained (contrast plotted against luminance) is different from that obtained when the visual task is detection. Follow-up studies conducted with real-life tasks and alphabets gave functions similar to those obtained with gratings. The psychophysical quantification of the functions will be accomplished by using a fluorescent system with reproductions of the NBS Microcopy Test Chart as the stimulus. These data will serve as the primary reference function from which recommended levels of illumination will be derived. The project is also working on the measurement and prediction of *lighting system effectiveness.* Preliminary studies indicate the *prediction* of lighting system effectiveness may be simplified, so that it can be more easily understood and used by the average

designer. The effect of these simplifications and other assumptions involved will be tested with various lighting systems.

A Guide for Window Design

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Sponsor: National Bureau of Standards

This work will result in a graphic table containing critical window design concerns on one axis, window component options on the other axis, and condensed information (presented graphically where appropriate) in the body of the table. This table will be a part of a pamphlet for building designers and owners, with a list of references for detailed information. Its contents would also be made available for incorporation in Architectural Graphic Standards and other building community publications.

Pedestrian Flow on Building Ramps

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Sponsor: National Bureau of Standards

The study of pedestrian flow on ramps is a project where measures of human movement are intended for use in ramp design guidelines and building regulations for ramps. Compared to other building circulation elements, there is relatively little pedestrian flow and design data available about ramps, tending to limit their wider use as a design alternative. It is anticipated that regulatory requirements for handicapped access to buildings will mandate much greater use of ramps.

Data in the form of video tapes of both ingress and egress at Baltimore Memorial Stadium comprise the data base from which pedestrian movement measures on ramps will be made.

From examinations of relationships between flow variables, predictions of their values can be made for the purpose of determining links between ramp characteristics and pedestrian flow. The major benefit of this project will be its contribution toward a better understanding of the relationship between the environment and human activities.

Materials

Research on the performance of roofing includes field testing of roofing materials, such as those found in bituminous built-up roofing systems.

Organic Coatings

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Sponsor: Department of Defense, Tri-Services Committee

The annual costs of organic coatings in the U.S. exceed eight billion dollars. Maintenance costs alone would be significantly reduced if better systems, including surface preparation, were available. In developing test methods and specifications, this project contributes directly to the improvement of the coatings technology used by the military and also contributes to improvement of the nation's coatings technology through publications, specifications, and participation in ASTM activities.

Field tests are being monitored to evaluate the performance of the new coating systems. In each case, the results obtained from a range of commercially available materials will be used as the basis for Federal or military specifications. The Paints and Protective Coatings Manual will undergo revision and will include sections on legislative restrictions of paint components, surface preparations, and a matrix table on paint compatibilities, etc. Also, advisory and consultative services, based upon laboratory and field tests will be performed. This year, a report will be published on the 5-year field test of lead-pigment free coatings. The Paints and Protective Coatings Manual will also be revised. Improved guidelines for the selection and use of organic coatings will lead to greater efficiency in the use of these materials.

Corrosion-Preventive Coatings

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Sponsor: U.S. Air Force

Inadequate performance of coatings on steel is costing the Air Force more than $50,000,000 per year. Most of their steel facilities must be recoated every 3 to 5 years despite the fact that modern industrial coating practices should give 10 to 20 years of useful life.

CBT's approach to this subject is in three phases: field surveys, laboratory studies, and the development of a guide specification. Initially, an informational questionnaire will be sent to all Air Force bases requesting their coating failure experience, which will be followed by selected on-site inspections. The laboratory phase will begin with a survey of candidate coatings, application procedures, and surface preparation methods. Based upon the laboratory and field tests, a guide specification will be developed for an effective corrosion-preventive system.

Results of this work will be distributed to researchers, manufacturers, consumers, contractors, and Federal, state, and local agencies. Publications in the open literature, specifications, and talks at professional and technical meetings will also accompany the completion of this study.

Durability of Coatings for Steel

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Sponsor: National Bureau of Standards

Protective coatings for the steel and wood used in buildings cost 4.5 billion dollars each year. The Steel Structures Painting Council seeks to reduce the costs of painting steel structures by increasing the painting cycle, but its work is hindered by the restrictions being placed on the constituents of paints (e.g., volatile solvents and lead pigments) by OHSA, EPA, and many other regulatory agencies. New and improved methods for evaluating the durability and protective qualities of coatings for steel are urgently needed if the new cost-effective coatings are to be recognized.

Under this project, the ASTM Methodology for Durability Prediction, developed by CBT, will be adapted to coatings for steel. The results will facilitate development of improved durability tests for coatings for wood and, consequently, improved selection criteria will be forthcoming.

White House Painting Study

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Sponsor: Department of Interior

The White House has been painted many times since the early 1800's. Since paint failures have been a continuing problem, this may be related to the following factors: the architectural design of the building, sandstone substrate, moisture infiltration, and adhesion problems related to the old paint layers. Data concerning this unique building are needed to provide an optimal approach to decisions concerning surface preparation, types of coatings, painting cycle, application methods, and the need for minimum disruption of the activities of the White House.

This project will initially include critical analyses of the historical records concerning painting practices and resulting difficulties. The literature will be searched for information on the types of potentially useful coatings, recommended surface preparation, and application procedures. Laboratory tests, e.g., adhesion, moisture retention, color retention, etc., will be made on a sandstone substrate and, based upon the results, field tests on selected areas of the White House will be conducted.

Based upon laboratory and field investigations, a guide specification will be developed for painting the White House. This specification will be part of a final report that will also contain detailed material requirements, project accomplishments, and recommendations for interim activities before the optimal program begins. The results will also be applicable to the maintenance of other historic buildings.

Preservation of St. Louis Courthouse

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Sponsor: National Park Service

The old St. Louis Courthouse is one of the most important historic structures located west of the Mississippi River. CBT is participating in a survey of the condition and composition of the materials used in the Courthouse. The first phase of the work will consist of a field inspection of the old St. Louis Courthouse for the purpose of identifying material problems. Samples of brick, mortar, and paint will be selected and analyzed. Based on the field inspection and laboratory work, recommendations will be developed to assist the NPS in the preservation of the Courthouse. Recommendations on preservation methods will then be developed. This project will contribute to the preservation of an important historic structure. In addition, through the project, methods for analyzing the materials of other historic structures will be developed.

Protected Membrane Roofing

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Sponsor: Department of Defense, Tri-Services Committee

Because protected membrane roofing systems use insulation above the membrane, the membrane is not subjected to large temperature changes, and is protected from traffic, solar radiation, and most external forces. Research has been carried out on the thermal performance of protected membrane roofing systems and tests have been conducted on their wind and fire resistance. Other than these data, little information is available on the performance of these roofing systems since they are relatively new and their performance has not been evaluated objectively.

In this project, the factors that affect the performance of test roofing systems will be identified. Properties of the various materials used in their construction will be reviewed as well as the interactions of the materials with each other. A field survey will be conducted to observe the condition and performance of the systems in different climatic locations. Information obtained from the literature search, discussions with knowledgeable personnel, and the field survey will be used as the basis for recommending guidelines.

Guidelines produced for the use of protected membrane roofing systems will provide increased performance of these systems and lead to less premature failures. Increased performance and less premature failures will result in economic savings. Further, energy will be conserved since insulated roofs that perform poorly or fail prematurely may not conserve energy efficiently.

U.S.-Canada Project for Monitoring Exposure Conditions

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Sponsor: National Bureau of Standards

Reliable evaluation of the performance and durability of new materials is important to the advancement of building technology. Although laboratory and natural exposures are used in evaluating the performance of materials, no generally satisfactory relationships between the effects of different exposure conditions have been developed. Better monitoring of exposure conditions is essential to improvement of durability technology, but electronic instruments can not be used at remote outdoor exposure sites because of the maintenance required. An alternate approach to measuring the intensity of solar radiation to which test samples are exposed involves the use of light sensitive plastics. This approach is being studied jointly by CBT and the Canadian National Research Council.

In this project, CBT will identify candidate materials and check their linearity of response to radiation in the laboratory. The sensitivity of the materials to factors other than sunlight will also be determined. Candidate materials will be exposed at CBT and NRC sites and calibrated against instrumental measurements of total and UV radiation. In the end, recommendations for new standards for radiation monitoring will be made to ASTM and ISO.

Roofing and Coating Research for the Army

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Sponsor: U.S. Army

The U.S. Army is the owner of many buildings that vary in construction type and are located in a wide variety of geographic and climatic areas. Since roofing and coatings have been the source of problems for most types of buildings in the U.S. Army, it offers an opportunity to apply laboratory research studies and practical field experience to the solution of special problems. Through problem-solving activities, areas of research may be identified and information may be obtained to help develop or modify standards, specifications, and criteria.

This work includes carrying out laboratory tests and evaluations in the solution of problems as well as field investigations. Recommendations will be made with regard to the selection of materials and application methods. The solution to these problems will also benefit other governmental agencies and the private sector by eliminating or reducing unanticipated early roofing and coatings failures.

Performance of Roofing

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Sponsor: National Bureau of Standards

Two billion dollars are spent annually on the repair and replacement of waterproofing membranes on low-slope roofs. Unsatisfactory performance of roofing membranes is attributed to many factors, including inadequate resistance to wind-uplift forces and splitting caused by excessive stresses in the membrane. ASTM and others (roofing contractors, architects, building

maintenance personnel, building owners, and materials producers) consider it urgent that action be taken to develop a standard test method to minimize losses from uplift forces caused by wind. There is a need to describe mathematically the performance of membrane roofing. It is also relevant that CBT is participating in an international committee, RILEM 31-PCM, to assist in the development of performance criteria for roofing.

In the wind-uplift study, the main candidates as standard tests will be evaluated in cooperation with ASTM. The performance of stressed roofing membranes will be modeled and compared to available data. Performance criteria will be developed based on available data as part of the RILEM committee activity. This international cooperation in the development of performance criteria for roofing will help avoid unnecessary duplication of efforts and to direct the resources toward a common goal.

Polystyrene Roof Insulation

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Sponsor: Department of Defense, Tri-Services Committee

The energy crisis has increased the interest in the use of foamed plastic insulation for roofing. Although polystyrene has excellent thermal resistance, it has properties which may lead to unsatisfactory performance of the roofing system. Criteria are needed for the design of roofing systems and the selection of materials for roofing systems that include polystyrene insulation between the deck and the membrane. The sponsor, the Tri-Services Committee, other government agencies, and the private sector need information to allow the selection of roof insulation materials that will perform satisfactorily as part of a composite roof system.

Among other studies, this work will include laboratory tests on various polystyrene rigid board insulations to measure properties such as shear strength, impact resistance, compressive strength, flexural strength, coefficient of thermal expansion, and water vapor permeability. A final report will be prepared with recommendations.

Visual Techniques in Non-Destructive Evaluation (NDE)

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Sponsor: National Bureau of Standards

In radiography, magnetic particle, and penetrant techniques in NDE, the human eye is used to detect and measure imperfections. Since the eye is being used, standardized visual tests are required to evaluate the performance of the human eye. Much is known about visual processes, *per se,* but the visual conditions, techniques, and information capacity required of the observer, as specifically related to NDE, are not firmly established. Field observations and interviews with NDE experts to identify the visual information associated with typical NDE tasks will be conducted. Microphotometric and microdensitometric measurements will be made of NDE tasks encountered in practice. These quantitative

descriptions of defect parameters will serve as the base from which visual standards and methodology to assess and calibrate the eye will be derived.

These visual standards in turn will minimize the variability in fault detection performance, a serious problem in visual NDE methods. The information and recommendations resulting from the study will be forwarded to the American Society of Non-Destructive Testing, ASME, and other special-interest groups (Air Transport Association, U.S. Air Force) for their consideration.

NDE of Building Materials

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Sponsor: National Bureau of Standards

The application of nondestructive evaluation (NDE) techniques to building materials is gaining increased importance because of the need for the rapid and reliable inspection of in-place materials. The present range of conventional techniques for inspection is often inadequate to meet the requirements encountered in modern rapid construction practices, in the rehabilitation of buildings, in the preservation of historic structures, and in the maintenance of buildings in-service. In such cases, there is a need to supplement conventional testing methods with NDE techniques. In this project, the state-of-the-art of the use of NDE techniques during the inspection of new construction and in the inspection of existing structures will be addressed during a Federal workshop (April 1978). In addition, research needs related to the application of NDE techniques to building materials will be identified. The feasibility of using microwaves to measure the moisture flow patterns in inorganic building materials, such as concrete, stone and earth, will be investigated. This project will contribute to developing an NDE method that can be used in inspecting new construction and existing structures.

NDE of Moisture in Roofs

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Sponsor: U.S. Air Force

Early detection of moisture in roofing is needed if deterioration is to be prevented. However, the usual methods of inspection for moisture are slow, costly, require cutting samples from the roof, and seldom provide conclusive results. The best hope for improvement of inspection procedures and improvement of roofing maintenance programs is through nondestructive evaluation (NDE) that will permit reliable identification of wet areas of insulation and membrane.

There are currently a number of promising nondestructive evaluation methods such as nuclear radiation, electrical capacitance, infrared thermography, and infrared photography. Still, many uncertainties exist, and a comprehensive study is needed to compare the accuracies of these methods and their applicability so that their proper role in roofing maintenance and repair

programs can be established. This project will study these areas. In it, CBT will analyze results from the various techniques, and guidelines and criteria will be established for selecting the more effective methods.

Creep and Drying Shrinkage of Concretes

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Sponsor: National Bureau of Standards

The trend toward lighter weight in buildings coupled with the increasing scarcity of good-quality, natural concrete aggregates has led to the increased use of manufactured, lightweight aggregates. Confidence in the use of the natural, normal-weight aggregates has developed, through experience, over a long period of time. Equivalent confidence in the use of the lightweight aggregates is developing, but would be enhanced by long-term performance data on concretes made with such aggregates. The magnitudes of long-term length changes in concrete are such that they lead to increased deflection, loss of prestress, cracking, and movement in concrete elements, all resulting in maintenance costs. While improvements have been made in the ability to predict these changes, they are basically long-term effects and there is a need to update existing data with long-term observations to allow better prediction of the changes and lead to reduced maintenance costs.

In 1964, NBS published Monograph 74 which included short-term data on the mechanical properties of concretes made from 25 different lightweight and 5 different normal weight aggregates. Subsequently, data on the strengths, creep and drying shrinkage for ages up to 12 years were developed for the same concretes. These data will be evaluated to supplement or replace the published data.

Modeling of Concrete Performance

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Sponsor: National Bureau of Standards

Portland cement concrete is the most widely used building material in the U.S. About 700 million tons is used annually. However, the selection of materials for use in concrete is largely empirical. Conservation of energy and materials are encouraging the substitution of blended cements for portland cements and the use of waste materials as constituents of concrete. To ensure that material substitutions do not cause unnecessary risks, a better basis for predicting the performance of concrete is needed.

Under this project, a conceptual model and computer program for modeling the hardening of cement will be developed. Beginning with the mixing of cement with water, the course of the chemical reactions taking place will be modeled and used to predict setting, strength development, heat evolution, and volume change. The validity of the model will be checked against laboratory data for single cement compounds and against data for portland cements. The composition of the liquid within the pores of hardened cement will be

used to predict the potential of different cements for deleterious reactions with aggregates in concrete. Finally, the model will be applied to prediction of the early age strength development of concrete at different temperatures.

In the end, the model will provide researchers with a tool for testing hypotheses about the performance of cement and concrete which will aid in the planning of research. It will also contribute to understanding differences in performance between different cements.

Lead Paint Hazards

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Sponsor: Department of Housing and Urban Development

The objectives of this project are: (1) the evaluation of new portable x-ray fluorescent (XRE) lead analyzer prototypes, developed under HUD contracts; (2) the development of lead paint reference materials for use in assessing the performance of lead analyzers and calibrating them; (3) the provision of technical services to HUD and other public agencies regarding the use of lead analyzers and housing survey methodologies; (4) the evaluation of the relationships between lead poisoning of children and the incidence and levels of lead in various environmental components; (5) the evalluation of materials and techniques proposed for use in lead paint hazard abatement by means of engineering judgment, laboratory testing, field testing, and field demonstrations; and (6) economic studies of the techniques used in the Experimental Hazard Elimination Program (EHEP).

Two outputs of the study will be a paper on the evaluation of the XRF lead detectors and new standard reference materials for use with them, and an economics report outlining EHEP cost models and how they can be used by public officials and housing and building owners.

Test Methods for Fly Ashes

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Sponsor: National Bureau of Standards

A proposed use of waste glass from municipal refuse is as an aggregate in portland cement concrete. However, the alkalies in portland cement react with many types of glasses to form expansive products that can lead to the cracking of the concrete. These expansive alkali-aggregate reactions often can be mitigated by the addition of certain fly ashes.

In this project, the effectiveness of different fly ashes in mitigating expansive alkali-aggregate reactions will be evaluated using both the synthetic aggregate specified in ASTM C-441 and a beltane opal, the use of which as the standard aggregate has been recently proposed. In addition, the effects of varying the mix proportions of the cement mortar will be investigated.

Safety

CBT engineers are studying the mechanism of formwork collapse.

Slip-Resistance Criteria for Walkways

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Sponsor: National Bureau of Standards

Current standards for slip-resistance of walkway surfaces are inadequate in that they do not contain quantitative criteria. Available data on floor friction are too closely associated with the type of apparatus used, operator techniques, and other variables to be given broad significance. The lack of accepted reference surfaces makes it impossible to accept the validity of slip-resistance measurements taken at different laboratories, with different testers, or under different conditions. This has a direct impact on public and private standards organizations and on the flooring, wax and polish, paint and varnish, building maintenance, and shoe industries. The concept of "generally accepted industry practice" is meaningless without quantitative criteria.

The NBS/CBT-Brungraber slip tester will measure the slip-resistance of a variety of materials and identify candidate reference materials. Candidate materials will be precisely evaluated utilizing a laboratory calibration table. A report entitled, "Proposed Reference Standard Surfaces for Laboratory or Field Calibration of Devices Used to Measure Walkway Slip-Resistance," will be prepared. In the end, the development of reference surfaces is equivalent to establishing a "yardstick" for slip-resistance measurements. Without a set of generally accepted surfaces, it is virtually impossible to relate slip-resistance measurements surfaces taken at different laboratories.

OSHA Technical and Scientific Support

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Sponsor: Occupational Safety and Health Administration

The Occupational Safety and Health Administration (OSHA), under Public Law 91-596, is charged with assuring a safe and healthful environment for workers. In conjunction with this charter, OSHA promulgates standards for all workplaces associated with interstate commerce. OSHA is currently upgrading all its standards. Many have been found to lack technical soundness and provisional justification. Research is necessary in these cases to develop provisions that provide the necessary minimum level of safety, based on sound technical rationale. These standards must be provided quickly to avert the economic and human consequences of delay. CBT provides technical assistance through the preparation of performance criteria, research, consultation and advisory services to OSHA.

The overall goal of this project is to provide support in a systematic fashion, incorporating the individual activities of all the projects into an effective general product for OSHA's use. This includes coordinating project outputs with OSHA's standards upgrading, formal notices, and activities.

Safety Requirements for Construction

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Sponsor: National Bureau of Standards

At present, OSHA relies on ANSI Committee A10 as the principal source of standards information for its regulations. But there is an urgent need for updating existing ANSI standards with the most recent scientific and engineering data to serve as an adequate technical base for the development of realistic standards directed towards safe and cost-effective construction procedures.

CBT has the lead role in developing and providing the basic technical information for updating specific safety standards, particularly in the area of concrete construction, trenching, and excavations, but also including such construction systems as scaffolding, safety nets, etc. CBT participates in committee activities and contributes to updating standards in areas where new research information is available or where studies are currently underway.

Fire Zone Safety: Economic Analysis

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Building Economics and Regulatory Technology Division

Sponsor: National Bureau of Standards

This project will provide decision-makers with an easy-to-use procedure for comparing the costs of alternative methods of retrofitting a fire zone in a health care facility to bring about compliance with the Life Safety Code. Compliance with the Life Safety Code will be determined by the equivalency methodologies of the Fire Safety Evaluation System developed by the Center for Fire Research. This project should therefore promote the use of more cost-effective means for upgrading the fire safety attributes of health care facilities.

The approach will first require a review of selected portions of the Life Safety Code to identify alternative fire zone retrofit options. Costs as a function of specific building and fire zone characteristics will then be determined. A computer model that identifies the expected costs of retrofitting the fire zone will then be developed. The cost model will then be tested for accuracy by validating its results against cost data collected under field retrofitting operations.

Door and Window Security Demonstration

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Sponsor: Department of Housing and Urban Development

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

Housing and Urban Development's Minimum Property Standards. These recommendations will result in revised and/or amended standards and building codes that will provide for more burglar-resistant doors and windows and thereby contribute to reducing the number of burglaries.

Building Security Technology: Research and Symposium

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Sponsor: National Bureau of Standards

This project is aimed at preparing and managing a co-sponsored (CBT and ASTM) national symposium. A good theoretical base for security that can be used by building managers, owners, designers, and programmers is nonexistent at this time. This project will contribute a significant and comprehensive literature base from which future security planning can benefit and to which future symposia can add.

Members of the Symposium include representatives of hardware manufacturers, security planning consultants, and the Federal government. The ASTM Executive Committee has agreed to give its full support and assistance. This symposium is expected to be held in the spring of 1979 and the final publication to be issued in the fall of 1979. This publication will be a combined ASTM/NBS publication and be distributed by NBS and ASTM.

As part of this project a technical report on past CBT research on door and window security will be prepared. In addition, a paper will be prepared that will explain how the CBT study of door and window security was planned and what the results can be expected to imply for future door and window design.

Building Security Standards ASTM F-12 Participation

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Sponsor: National Bureau of Standards

This project will support the adoption of a security standard for windows by ANSI/ASTM. The project leader will serve as chairman of ASTM Committee F-12 on Security Systems and Equipment and in addition, assist in the technical study recently recommended by the International Conference of Building Officials (ICBO) for the purpose of adopting parts of the door and window security standards into the Uniform Building Code.

Security standards for doors and windows have been developed by CBT in the recent past under the sponsorship of the Department of Justice's Law Enforcement Assistance Administration (LEAA). This support stopped before implementation of the standards was completed.

Based on the present security standard for windows, a Standard Method of Test has been prepared in draft form and was presented to the ASTM window task group and appropriate sub-committees. Included will be the necessary defense, response, and possible reiteration

of the standard for ultimate approval by the sub-committees and adoption by ANSI/ASTM. In detail, this will be done by the preparation of presentations and correspondence, by attending and calling meetings of sub-committee and committee members. The products of this project include an ANSI/ASTM Standard Methods of Test for the Security of Windows and the adoption by ICBO of door and window security requirements as part of the Uniform Building Code.

Electrical Distribution Systems

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Sponsor: National Bureau of Standards

There is a need to alter the prescriptive approaches imposed by the National Electrical Code on electrical wiring systems for residential use. The increased costs of housing as a result of regulatory constraints are the concern of HUD as well as builders, developers, and consumers. There is a need to modify existing codes and an emerging need for special codes applicable to rehabilitation of buildings. The expanding confusion of regulations requiring Ground Fault Circuit Interrupters are being questioned with respect to cost-effectiveness, safety, and total energy usage.

Further, innovative energy conserving or alternative energy sources, such as fuel cells, wind power, and solar electrical power supply, will require new regulations and requirements for special circuitry frequencies and voltage levels. The national energy conservation retrofit program requires added thermal insulation in attics which will bury existing electrical wiring and boxes and can produce temperatures exceeding the allowable limits for conventional wiring systems.

In view of these matters, CBT will conduct a detailed review of the NEC to identify prescriptive code language that restricts innovative electrical systems in buildings. CBT will also develop electrical service systems and controls requirements with performance-oriented criteria and guidelines. Further test needs will also be established.

The project results will be given to the appropriate panels of NEC and ANSI and to manufacturing groups and professional societies such as the National Electrical Manufacturing Association and Institute of Electrical and Electronic Engineers. Present HUD and ERDA program interests in community requirements for evaluation of small-scale electrical power supplies will be provided with output from a load-demand review.

Innovative Electrical Wiring

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Sponsor: Department of Housing and Urban Development

Restrictions on the use of nonmetallic-sheathed cable in the National Electrical Code and other Codes and Standards are alleged to result in unnecessarily high costs of electrical wiring systems. Also, technological progress is alleged to be unduly hindered because innovative electrical wiring systems cannot be introduced into the building construction process until satisfying certain performance criteria. Because of the very serious hazards presented by electrical wiring systems, changes in Codes and Standards should be made only when justified with adequate technical data. Fire-starting mechanisms and other parameters involving electric shock and fire hazards are being characterized and quantified with appropriate electrical and thermal measures. After developing a basic understanding of the technical parameters involved, performance criteria and test methods will be developed for the evaluation of innovative and conventional electrical wiring systems.

To implement the results of this research changes in the National Electrical Code and changes to or development of other appropriate Codes and Standards will be proposed. Data and information will be provided to groups such as NCBCS, IEEE, NEMA, and ANSI.

Mobile Home Egress

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Sponsor: Department of Housing and Urban Development

This project will provide a quantitative basis for modification of the egress requirements of the HUD Mobile Home Construction and Safety Standards. Under it, interdisciplinary library and laboratory research will be carried out in the areas of physical and behavioral analysis of mobile home occupants, characteristics of egress devices, performance test development, hazard analysis, and economic impact. A summary report will document the technical basis of the recommended performance goals and justify expanding the scope of the standards. The report will include a proposed revision of the egress requirements of the standards. HUD will use the research and recommendations to make specific modifications to the Mobile Home Construction and Safety Standards. Research results may also serve as input to the NFPA Life-Safety code (NFPA 101) and other egress-related standards. The research will significantly upgrade the egress requirements of the HUD Mobile Home Construction and Safety Standards.

Mobile Home Purchase and Modification

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Sponsor: Department of Housing and Urban Development

This project will provide a quantitative basis for modification of the egress requirements of the HUD Mobile Home Construction and Safety Standards. CBT will use a late-model mobile home and construct egress devices that permit adjustment of the device characteristics such as size of opening, number of operating devices, and forces required to operate devices. HUD will use the research and recommendations to make specific modifications to the Mobile Home Construction and Safety Standards. Research results may also serve as input to the NFPA Life-Safety Code (NFPA 101) and other egress related standards.

Structures

Reinforced concrete masonry shear wall is being prepared for a test to evaluate its earthquake resistance.

Wind-Induced Response of Tall Buildings

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Sponsor: National Bureau of Standards

Within the past few years, the body of information concerning wind forces on structures, the physical parameters of the structures, and actual measurements of the response of structures to winds has grown considerably. Wind forces have been recorded on wind tunnel models and in a few cases on full scale structures. Provided that the loading is a stationary random process, the response spectrum of the structure can be estimated. Likewise, when the response of the structure is known, the effective load spectrum can, at least in part, be estimated. The accuracy of these estimates depends upon the validity of the mathematical model of the structure used, and the accuracy of wind load spectra applied, along with the assumptions about the correlation of the pressure fluctuations over the structure's surface.

The models that have been used to date have only been applied to the determination of the along-wind structural response. However, in some instances, the cross-wind response may be greater than the along-wind response and very few investigators even mention torsional response. This study seeks to deal with the cross-wind and torsional response spectra in addition to the along-wind response.

A result of the study will be the application of some new basic wind research information to the problem of estimating the response of a structure, along with an evaluation of the modeling process. Some idea of the influence of neighboring structures on the response of structures would also be obtained. The results of the study will be made available through widespread publication in technical journals. Results will also be presented to ANSI A58 as resource documents for possible modification and/or improvement of wind load provisions.

Criteria for Wind Tunnel Modeling

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Sponsor: National Bureau of Standards

The testing of structural models in a wind tunnel is a very effective method, and often the only available method, for establishing pressure, lift, and drag coefficients for the design of full-scale structures to resist the effects of wind. When properly conducted, these tests can result in substantial savings when compared to designs based entirely on the minimum load requirements specified in codes and standards. In recognition of this, the next edition of American National Standard A58.1 (Minimum Design Loads) will quite likely allow wind tunnel test data to be substituted for the usual wind load provisions. Therefore, it is essential to establish a set of requirements that will ensure the validity of wind tunnel set results.

Existing information on wind tunnel simulation of atmospheric surface flows will be reviewed. Results of a round-robin test sponsored by the Commonwealth Advisory Aeronautical Research Council will be of considerable value in determining the sensitivity of load

and response measurements to the various dimensionless scaling parameters in wind-tunnel modeling. It is anticipated that the degree to which these parameters must correspond in model and full-scale testing can be expressed in terms of the accuracy of the test results. The development of minimum requirements for wind tunnel modeling will substantially increase the range of structures covered by the A58.1 Standard and will lead to better load definition and, therefore, improved reliability and economy.

Probability Distributions of Extreme Winds

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Sponsor: National Science Foundation

CBT is the Secretariat for the ANSI A58.1 committee developing a revised standard for the design of structures to resist extreme winds. The revision of such a standard is required as many of the assumptions employed in previous standards have been shown to need updating. The project involves the collection of existing data from the National Climatic Center records; the evaluation of such data; the recording of the data in a format useful to the designer and code writer; the statistical analysis of the data; the development of criteria for estimating statistical errors; the development of criteria for specifying appropriate mean recurrence intervals for design purposes as functions of wind climate characteristics and the wind sensitivity of the structure. The results of the research will be used by designers and code writers as a basis for defining wind loads on structures.

Administration of Secretariat, ANSI A58

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Sponsor: National Bureau of Standards

NBS has provided the administrative continuity for evolving standards committees on building code requirements for design loads on building structures over the past 50 years. The interest evoked by the current ANSI Standard A58.1-1972 has demonstrated the need for such a consistent nationwide standard. However, its use by the model building codes has to be further encouraged; the latter are not consistent with respect to loadings on building structures. A consistent set of design loads should be used and 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. One problem arises due to differences in design philosophy; another problem that the committee is currently addressing is the confusion in the use of loads for steel and concrete structures. In recognition of these problems, the trend in Europe and Canada has been directed toward development of a common basis for design which would be applicable to all buildings. In the U.S., ANSI A58.1 appears to provide a logical vehicle for similar efforts to simplify design. CBT is coordinating the activities of Committee A58 to revise portions of the current standard by 1980.

Criteria for Loads and General Design

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Sponsor: National Bureau of Standards

Current design standards rely on different philosophies and criteria for design, depending on the material or construction technology used. This tends to complicate design when different technologies are employed in the same structure. Moreover, differences in philosophy (e.g., ultimate strength vs. working stress design) and a failure to consider uncertainties explicity causes a lack of consistency in the levels of reliability afforded different buildings. In recognition of these problems, the trend in Europe and Canada has been directed toward development of a common basis for design that would be applicable to all buildings regardless of their material or construction technology. To ensure adequate performance, the unifying concept of limit states has been used, along with a probabilistic treatment of the uncertainties invariably found in engineering design. In the U.S., ANSI A58.1 has appointed a committee to investigate the feasibility of developing probability-based criteria for limit states design. However, while the general methodologies developed above should be helpful, the specific criteria and numerical values cannot be assumed to be applicable to building standards in the U.S. Moreover, there is a need to clearly relate the proposed criteria to existing standards in the U.S. to gain professional acceptance. The research envisioned will assist in developing criteria for the design of building structures that would ensure adequate reliability against structural failure and unserviceability and would be appropriate for all materials and construction technologies.

The development and implementation of suitable technology-independent design criteria for all limit states would reduce building costs by simplifying the design process and stimulating market competition between construction technologies. Improved serviceability requirements would also result in less maintenance and increased occupant satisfaction.

Structural Performance of Solar Collectors

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Sponsor: Department of Energy

In designing solar collectors and their supports the effects of the aerodynamic loads induced by wind, the snow loads caused by drifting and accumulation around the collectors, the loads induced by seismic events, the resistance of collector systems or elements to the action of hail, and the temperature response of their structural supports, all must be known. For certain collector systems the technical information required for safe and economical design is not available. The purpose of this project is to identify these types, to obtain the required information, and to develop structural performance criteria and guidelines. The results of the research will be used by designers and code writers as a basis for design of solar collectors.

Seismic Design Provisions

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Sponsor: National Science Foundation

The problem of potential earthquake loss was significant enough for Congress to provide the National Science Foundation several million dollars to fund research and development over the past few years in a program to produce new seismic design provisions. This project is designed to facilitiate the goals of earthquake disaster mitigation by assuring that the design provisions produced are used in building regulations.

Three levels of analysis are used in work: (1) each provision will be examined for consistency and completeness, using decision tables where applicable; (2) a detailed information network will show all the provisions and their status of evaluation; (3) a detailed network of provision descriptors will be generated and used to test the scope and arrangement of the provisions. The first phase of the project was to analyze intermediate drafts and make appropriate recommendations. The final phase of the project will be to document the final draft by publishing a report containing decision tables and topological information for all of their provisions, with comments to guide future users of the provisions, future writers of similar provisions, future revisors of these provisions, and future users of our technology for analysis of standards and codes.

Seismic Design Provisions: Implementation

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Sponsor: National Science Foundation

In 1974, the National Science Foundation and the National Bureau of Standards, as part of the Cooperative Federal Program on Building Practices for Disaster Mitigation, undertook a project with the Applied Technology Council of the Structural Engineers Associations of California to develop comprehensive nationally applicable seismic design provisions for buildings. These design provisions were completed in FY 77 and reflect the current state of the art in earthquake engineering in a form adaptable for implementation by standards organizations, model code groups, Federal agencies, and other regulatory groups.

In view of the magnitude of the implementation effort and the need to include participation by a number of groups, a well-planned coordinated effort is required. The implementation phase must be national in scope and participation by national or regional organizations will be encouraged. Representatives from the current project noted above will participate to insure continuity.

A two-phase effort will be conducted to facilitate this participation. In the first phase, CBT will select the organizations and individuals to be involved in developing the plan. In the second phase, this input will be synthesized into a comprehensive plan. Detailed work statements will be prepared for all activities defining the objectives, procedures for conducting the work and the participants.

The implementation plan will be used to direct efforts toward incorporating the design provisions in codes and standards for use by state and local governments and Federal agencies. Adoption of these provisions in codes and standards should significantly reduce earthquake losses.

Seismic Resistance of Reinforced Masonry Shear Walls

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Sponsor: National Bureau of Standards

One of the most urgent problems in earthquake resistance masonry construction is the scarcity of research data on lightly reinforced masonry shear walls under the action of earthquake loads. This need was identified at the 1976 CBT/NSF National Masonry Workshop and was highlighted by the fact that most masonry research is focused on heavily reinforced masonry construction used in high seismic risk zones, although 90 percent of masonry built in the U.S. is outside these zones. The proposed research will examine the effect of light reinforcement on the seismic load capacity of diverse types of masonry shear walls. Simultaneously, the potential advantages of a new test method for use in seismic-related experimental research will be examined.

The proposed test method will be used to realistically reproduce actual stress and boundary conditions in masonry shear walls under the combined action of earthquake and gravity loads. The analytical component of the project will explore the experimental results to examine the effect of light reinforcement on precracking and postcracking shear wall limit states. An understanding of these limit states is fundamental in the formulation of improved design criteria for lightly reinforced masonry shear walls.

Building Practices for Disaster Mitigation

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Sponsor: National Bureau of Standards

Property losses from natural disasters such as floods, earthquakes, hurricanes, and tornadoes exceed one billion dollars annually. Disaster assistance legislation (PL 93-288) and the Earthquake Hazard Reduction Act of 1977 (PL 95-124) emphasize the need for hazard mitigation activities.

This continuing research program is directed toward developing improved building practices for structures subjected to extreme environments. Laboratory research, post-disaster investigations, and work with professional practitioners focus on developing these improved practices. Outputs planned for FY78 include: (1) seismic design provisions applicable to all areas of the United States; (2) a plan for implementing the seismic design provisions in model codes and Federal regulations; (3) preliminary reports on research needs for large-scale testing of structural components; (4) research proposals to other Federal agencies dealing with wind engineering and earthquake engineering.

The implementation plan for the seismic provisions will be developed by working with design professionals, professional organizations, trade associations, Federal agencies, and the building regulatory community. Large-scale testing research will be developed in conjunction with university researchers and government officials from the U.S. and Japan working through the U.S. Japan Panel on Wind and Seismic Effects. Proposals to other agencies will be developed by working directly with Federal officials responsible for building practices directed toward hazard mitigation.

Post-disaster investigations have demonstrated that the application of improved building practices can significantly reduce losses due to natural hazards. Adoption of the seismic design provisions by state and local governments and incorporation of NBS research results in design and construction should reduce annual hazard losses due to wind and earthquake by 25 percent by the year 2000.

Concrete Construction Technology

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Sponsor: National Bureau of Standards

Existing standards for concrete construction are non-uniform and ambiguous and are often the underlying factor in needless increases in construction costs. This is due primarily to a lack of research data and information in the area of concrete construction technology. Traditionally, design and erection of formwork and other construction-related work are based more on rule-of-thumb procedures rather than on sound engineering principles.

Significant reduction of concrete building cost can be achieved through increased rate of construction cycle and repetitive use of formwork, as the cost of formwork can be as much as 60 percent of the total concrete construction. The rate at which concrete construction can progress is dependent largely on the rate of strength and stiffness gain of concrete, and an accurate determination of construction load distribution between the structure and the formwork. CBT will undertake a field study of construction practices to document erection imperfections, and carry out analytical investigation of shore capacities. A computer model simulating the construction process will be developed to study parameters that affect the distribution of loads between formwork and the structure during construction. Finally, CBT will develop shoring and reshoring criteria.

Technical information developed in this study will be made available to both the ANSI A10.9 Standards Committee and ACI 347 Standards Committee on Concrete Construction.

Thermal Loads on Concrete Slabs

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Sponsor: Federal Highway Administration

Thermally induced stresses or strains may affect significantly the performance of structures in service. Many sources of thermal-type loads exist in buildings and the resulting expansion and contraction may open joints or cause cracking. It is known that thermal loads may be severe for certain types of composite construction. In this project, a computer program will be developed to predict the magnitude of strains generated by heating a portion of a concrete slab. The program will be generally applicable to slabs with various support conditions and boundary constraints. Output from the program will be strain or stress levels at various points on the bridge deck (both heated and unheated areas) at various times during heating and subsequent cooling. The location of any areas of predicted cracking will also be defined. The computer analysis will be checked by analyzing two bridge decks that have been heated and by comparing the computer predictions with cracking actually observed.

Consolidation of Masonry Standards

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Sponsor: National Bureau of Standards

The volume of masonry construction in the United States now exceeds $5 billion. In spite of this volume present masonry standards are fragmented and sometimes contradictory. The only existing national standard, A41, was issued in 1952 and does not reflect the current state-of-the-art. The chairmanship of ANSI A41 is held by CBT. Under this chairmanship a draft empirical standard has been prepared and is in final review before distribution for balloting by committee. This draft standard will be completed and balloted during FY78 and ready for issuing by ANSI during FY79 as a national standard for non-engineered masonry construction. The conclusion of this activity will be an opportune time for the ANSI committee to consolidate with other masonry committees. Initial contacts with the American Concrete Institute and the American Society of Civil Engineers have been favorable towards the idea of consolidation. Industry contacts have also been favorable towards accepting the recommendations of a consolidated committee.

Fire-Resistant Structural Design

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Sponsor: National Bureau of Standards

Losses due to fire in the U.S. exceed losses from the effects of other extreme environmental factors normally considered in structural design. Fire resistivity of structures is currently measured by the endurance of temperature rise in certain members subjected to a standard ASTM fire test. Such tests are very costly and provide little basis for extrapolating to situations not covered by the limited data base. There is also evidence that the ASTM fire test is an inadequate indicator of structural performance during an actual fire. Finally, uncertainties in the duration and severity of fires and in

material properties suggest that design criteria should have a probabilistic basis. Analytical procedures being developed at CBT and elsewhere show promise in predicting structural behavior under severe fires. These procedures should be validated experimentally, however, before they are used to develop design criteria. Moreover, the feasibility of considering other fires for design besides the standard ASTM fire, should be investigated.

Under this project, the aim is to develop fire-resistant design procedures that allow structural-member-performance criteria to be satisfied and that reflect uncertainties in structural behavior. With the assistance the NBS Center for Fire Research (CFR), alternate design fire curves will be established and member behavior under current fire design criteria will be examined. Computerized thermal and structural analyses will be validated through a collaborative test program with CFR and CBT. Effects of variation in fire and material parameters will be studied using simple beam and slab configurations.

Alaska Pipeline Vertical Support Members

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Sponsor: Department of Transportation

The design of the vertical support members (VSM) of the Trans-Alaska Crude Oil Pipeline System has been under review and discussion by a number of experts in permafrost engineering for quite some time because this type of system has not been used extensively in permafrost before. Conditional approval of the design was issued by the Alaska Pipeline Office in 1976. Because of the unusual design of the VSM and the influence of their performance on the structural integrity of the pipeline, an indepedent review of documentation on the system is being funded by the Office of Pipeline Safety Operations (OPSO), Department of Transportation. The adequacy of the aboveground support system is likewise of concern to the House Subcommittee on Energy and Power and this review is also being conducted in response to that concern.

Appropriate documentation concerning analysis and design of the VSM under earthquake loading, metallurgical properties of the VSM, low-temperature effects, load testing and miscellaneous studies relating to the VSM will be reviewed. Critical comments regarding the use of good engineering practice relating to the design load criteria for the VSM system and the resultant effects of low temperatures on the steels used in the VSM will be provided. If this assessment of the design indicates the need for remedial action to assure structural integrity, general guidance will be provided to OPSO.

Evaluation of Air Mobile Shelter Systems

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Sponsor: United States Air Force

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

It is expected that the performance criteria will be incorporated into the procurement procedure for air mobile shelters. The criteria will replace some of the end-item tests now used in the acceptance evaluation of shelter systems. The U.S. military will have increased capability in evaluating the various shelter designs and in procuring shelter systems for its many applications. The performance criteria developed during this project should enable the Air Force and other military branches to make more reliable predictions of shelter response to transportation, handling, and field service loads. As a consequence, the services should be able to purchase more cost-effective and more maintenance-free shelter systems.

Improvement of Honeycomb Cores

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Sponsor: U.S. Army, Natick Laboratory

All branches of the military use lightweight, air-transportable, rigid structures that serve as combination shipping containers and shelters for many types of tactical and life-support services. The use of these shelters has increased so rapidly in recent years that life-cycle costs have become a major economic factor. These shelters are fabricated from either paper honeycomb core or foamed plastic sandwich panels. The honeycomb panels have been found to be more satisfactory for some types of shelters. However, field experience has indicated poor performance of some honeycomb shelters. The poor performance has been attributed to one or more of four basic factors. These factors are: improper panel fabrication procedures (adhesive bonding), inadequate performance of the honeycomb core, poor choice of materials, and inadequate design.

CBT researchers will contribute to the development of both military and ASTM specifications for materials and processes to be used in fabricating honeycomb core panels for military shelters. In addition, data from laboratory studies will be prepared for the sponsor. Research results will be transferred at meetings attended by technical personnel from all branches of the military and from most segments of the shelter industry. These

meetings are held under the auspices of an ASTM subcommittee (E6.22). The information and data circulated will be used almost immediately by the military shelter industry.

Review of Liquified Natural Gas Facilities

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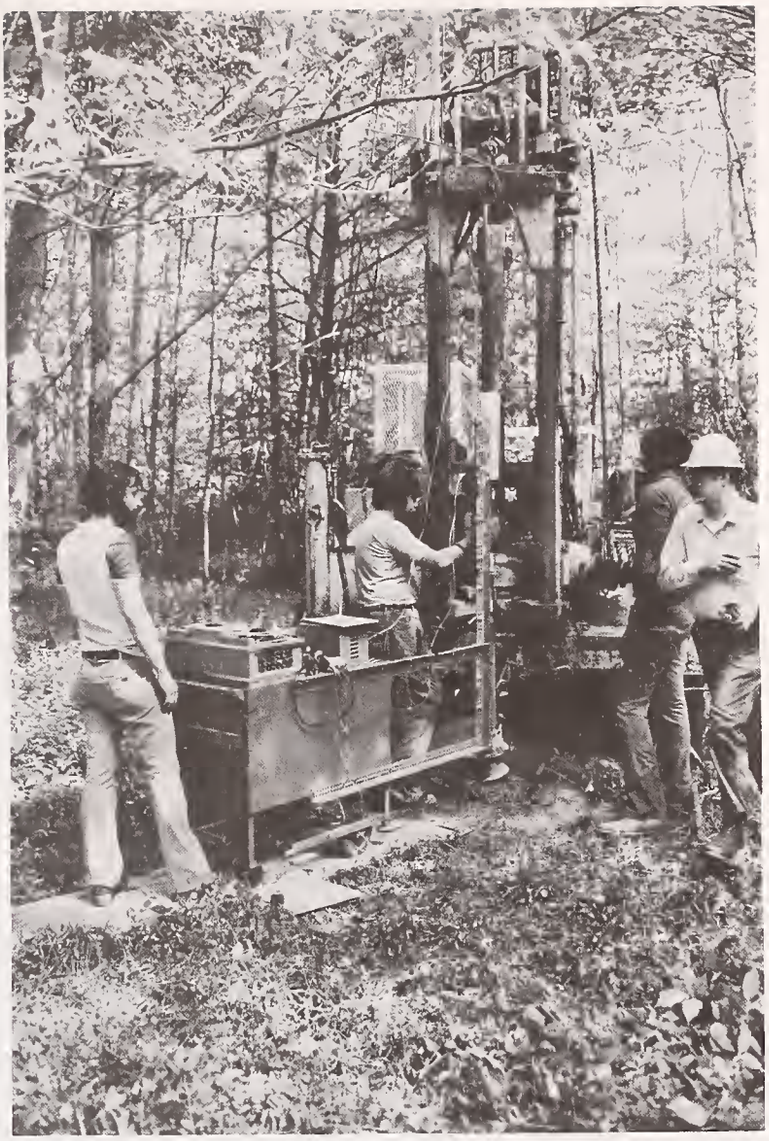
Sponsor: Federal Energy Regulatory Commission

The Federal Energy Regulatory Commission (FERC) is authorized to issue certificates of public convenience and necessity for the construction and operation of natural gas facilities subject to its jurisdiction. CBT has been requested by the FERC to critique structural and geotechnical aspects of proposed LNG facilities on a case-by-case basis. The CBT review is used by the FERC in their overall evaluation for the consideration of approval for construction.

The design criteria for the facilities will be evaluated by comparison with sound engineering practice, state-of-the-art techniques, and requirements for nuclear power plants. Where data are insufficient to complete evaluation, a list of required information will be provided to the FERC.

Geotechnical Engineering



Field test is being performed on the standard penetration test apparatus.

OSHA Excavation Standards Study

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Sponsor: Occupational Safety and Health Administration

Excavation for building construction is a matter of major concern to the industry. Recent OSHA regulations for braced and unbraced excavations have considerable impact on the cost of construction and are therefore a subject of criticism and concern by engineers and contractors. In many cases improper side slopes in shallow excavations or inadequate shoring of deep excavations result in collapse with tragic consequences. A measure of the seriousness of this problem can be derived from the fact that in 1973 alone, 226 people lost their lives as a result of slope failures in shallow excavations. At least three times as many fatalities occur as a result of the collapse of deep excavations.

This project will develop improved guidelines for such excavations. OHSA provisions are incomplete, difficult to enforce, and in urgent need of revision. The key to effective excavation safety provisions, which will protect workers at a reasonable and acceptable cost, lies in the ability to accurately predict the forces acting on excavation bracing and determine the maximum slope for stable soil condition.

Calibration of Standard Penetration Tests

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Sponsor: National Bureau of Standards

The Standard Penetration Test (SPT) is used in about 90 percent of the routine foundation engineering designs in the U.S. At the present time test results are fluctuating due to many non-standardized variables. There is also considerable confusion in the interpretation of European and Japanese test results relative to U.S. data due to variation in delivered kinetic energy during the test. This confusion in turn raises doubts about the validity of our interpretation of available data in critical problem areas such as liquefaction caused by earthquakes.

To settle these questions, a portable field instrument will be built to measure fall height, hammer velocity, and force in a drill stem, and present these quantities in the form of energy immediately following a test. To ensure reliability of measurement, the instrument will use two systems: an optical system measuring hammer velocity and energy above the striker plate, and a mechanical system measuring the stress wave traveling through the rod to measure the energy in the rod *below* the striker plate. After field tests and calibration, a study will be conducted to evaluate the delivered energy, both above and below the striker plate, and show the variation of energy, some of which may be due to hammer configuration.

The draft standard resulting from this research will be submitted to ASTM Committee D18.02 for consideration. The expansion and improvement of the data base will drastically improve our knowledge on important phenomena, such as liquefaction.

Performance Standards for Foundations and Excavations

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Sponsor: Department of Housing and Urban Development

Damage to structures and improvements directly attributable to failure or distress associated with foundation problems exceeds $3 billion annually. In addition, many major engineering projects, such as mass transportation systems, sewerage, water supply, and other utilities, require large-scale excavation in urban areas. These are expensive to construct and can cause extensive damage to adjacent structures. Major difficulties, costly failures, and much litigation result from the fact that provisions for foundations and excavations in existing codes are inadequate and in some instances ambiguous, conflicting, overly rigid, and prescriptive. There is a need for national standards that can be adopted by the building codes and uniformly applied throughout the U.S. CBT is taking part in the drafting and the consensus review process of getting these standards accepted.

Anchoring Mechanics for Mobile Homes

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Sponsor: Department of Housing and Urban Development

Next to fire, wind is the leading cause of deaths and injuries of mobile home occupants and damage to mobile home property. Approximately 5,000 units are heavily damaged or destroyed by wind storms each year. Another important source of property damage are floods. Mobile homes themselves are vulnerable to flood damage; furthermore, mobile homes which are inadequately anchored can float and cause substantial secondary damage downstream by obstructing the flow through channels and bridges. Thus, it is crucial to adequately anchor mobile homes to the ground so they can resist the uplift and lateral forces associated with wind and floods.

Criteria for the determination of wind forces were developed in a recent NBS project. This project will address itself to three topics: (1) development of criteria for the determination of forces associated with floods; (2) determination of the soil-resistance of miscellaneous soil anchor systems; (3) development of performance tests to determine the adequacy of soil anchor systems.

The project will impact the problem through mandatory provisions in the Federal Mobile Home Construction and Safety Standards. The project also will provide HUD with basic information required to formulate design criteria and performance tests appropriate for inclusion in the Federal Mobile Home Construction and Safety Standards. These research efforts will have a significant impact on the safety and durability of mobile homes because future anchoring provisions of the mandatory standards will be based in large part on the findings of this study.

Research Needs and Priorities for Geotechnical Earthquake Engineering Application

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Sponsor: National Science Foundation

Soils are a critical constituent of most civil engineering structures including earth dams, foundations for buildings, buried utilities and life lines, highways, harbors, and urban development tracts. Examples of poor soil behavior in past earthquakes are the $1 billion loss associated with soil liquefaction in the Niigata, Japan earthquake; catastrophic landslides, and damage associated with soil liquefaction in the 1964 Alaska earthquake; the great fire in the 1906 San Francisco earthquake which was the result of the destruction of water lines; the catastrophic landslide in the 1972 Peru earthquake; and the near failure of the San Fernando dam in the 1971 earthquake, which could have resulted in the loss of 80,000 lives.

To provide guidance to researchers and to the National Science Foundation, a 2-day workshop was held at the University of Texas at Austin on June 2-3, 1977, for the purpose of obtaining and synthesizing professional opinions from knowledgeable people concerning research needs and priorities in geotechnical earthquake engineering. Seventy-three participants from the United States, Canada, and Mexico attended. The workshop was composed of a series of group discussions of small numbers of experts on the following seven topics areas: (1) dynamic soil properties and measurement techniques in the laboratory; (2) dynamic soil properties and measurement techniques in the field; (3) analytical procedures and mathematical modeling; (4) design earthquakes, ground motion, and surface faulting; (5) assessment of seismic stability of soil; (6) soil structure interaction; and (7) experimental modeling and simulation.

A report summarizing and synthesizing opinions expressed and recommendations made by these group discussions will be published as an NBS Building Science Series report.

Construction of Housing in Mine Subsidence Areas

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Structures and Materials Division

Sponsor: Department of Housing and Urban Development

Subsidence caused by the collapse of abandoned and active underground mines poses a major threat to buildings and utilities on the ground surface. At present, 7.5 million acres in the United States are undermined and about one-third of this area experiences serious subsidence problems. Coal is now being mined at a rate of 100,000 acres per year and it is planned to quadruple this rate in the next 2 to 3 years. It would not be economically feasible to prohibit residential development in all these areas. Thus, mine subsidence poses a serious problem to the United States' economy.

In this project, interim guidelines based on present knowledge were developed for the construction of housing in mine subsidence areas. The guidelines are being reviewed by a consulting panel. The guidelines deal with three areas: site development, site evaluation, and building construction. As there are now no other U.S. guidelines or standards in this area, this work will have considerable impact on construction practices in mine areas.

Codes & Standards

Extending the useful life of the available housing stock through renovation of existing buildings can provide an economical way to reduce the high cost of new construction.

Rehabilitation of Existing Buildings

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Sponsor: National Bureau of Standards

The cost of construction of new buildings will continue to increase faster than the cost of living. Extending the useful life of the available housing stock through the renovation of existing buildings can provide an economical way to alleviate this trend. However, adequate technical bases for building regulations necessary for upgrading buildings to provide acceptable levels of health, safety, and serviceability do not currently exist.

Under this project, a program plan will be developed for CBT activities relative to the regulatory aspects of building rehabilitation. The specific elements of the program will include (1) support in the development of model rehabilitation code provisions including the formulation of performance provisions, limit states and compliance levels, where possible. The model provisions will be developed by NCSBCS and the model code organizations with funding largely outside this project, (2) development of general guidelines for the application of system trade-offs in applications of performance based code provisions, as well as, outlines of manuals containing state-of-the-art listing of technical data for the following attributes; (a) health and sanitation, (b) accident safety, and (c) strength and stability. The anticipated data will include test methods for evaluation of existing constructions, methods of analysis, inspection and evaluation methodologies, data on performance of archaic systems, and data on rehabilitation experiences; and (3) state-of-the-art collection of the type of regulatory processes employed in a sampling of local government jurisdictions involved in various types of rehabilitation activity.

Building Codes and Standards Improvement

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Sponsor: National Bureau of Standards

This project is directly related to implementation of NBS building research results through building standards and codes. It will provide strong ties between CBT research and the entire building standards and codes community which will expedite early acceptance and timely implementation of CBT research into building codes and regulations, provide effective technical consultation on building research relating to proposed code changes, assist in developing and implementing performance criteria to replace prescriptive requirements, provide technical assistance and research results in furtherance of greater uniformity in building regulations, and provide technical assistance in support of adoption and implementation of uniform building regulations.

Performance of Building Construction ASTM E06

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Sponsor: National Bureau of Standards

ASTM Committee E06 "Performance of Building Construction" includes in its scope "the standardization of methods of test for building construction, elements, connections and assemblies, under actual or simulated service conditions applicable to the evaluation of such factors as materials, design, construction and fabrications." Since this scope is closely related to the work in CBT, ten staff members participate on the Main Committee and Subcommittees of E06. This project provides the coordination of this committee activity.

NIBS Technical Support

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Sponsor: National Bureau of Standards

The National Institute of Building Sciences (NIBS) was established by Public Law 93-383. The Center's role is to provide technical services and technical studies to the Board of Directors of NIBS to assist them in organizing NIBS to develop, promulgate, and maintain nationally recognized performance criteria, standards, and other technical provisions. CBT has become more involved in technical studies in the following general areas: utilization of building standards in building regulation, identification of technical issues and problem areas related to development of performance standards and criteria, and preferred structure and format for performance standards and criteria.

This project is closely related to the implementation of CBT research results. Since NIBS is broadly representative of the building community, it is expected to be a major user of CBT research, converting such research into performance-based standards for use in building regulations.

Research Conference on the Building Regulatory Process

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Building Economics and Regulatory Technology Division

Sponsor: National Bureau of Standards

This annual conference is intended to inform and assist decision-makers in the regulatory area by reporting on building regulatory developments that advance or retard technological change. Why is this necessary? Because regulatory policy is too often made and enforced without the benefit of objective knowledge of the impacts of those policies on the building community and whether those policies are achieving the desired effect. Two prior conferences have been successfully completed under joint sponsorship with NCSBCS and have shown a steady increase in interest and attendance by all sectors of the building community. The proceedings of the First NBS/NCSBCS Joint Conference (Providence, RI, September 1976) were published as SP 473, *Research and Innovation in the Building Regulatory Process* and have been well received by many audiences. For instance, the publication has been used as the primary text in a graduate seminar in architecture at the University of Illinois.

Assessment of Building Regulatory Systems

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Sponsor: National Bureau of Standards

In the last ten years, the extent and degree of building regulation has considerably expanded. Building codes and standards and the associated mechanisms by which they are adopted, administered, and enforced have been identified as containing and creating several problems for society in general and the building community in particular. Rarely, if ever, are these regulations and practices systematically reviewed to assess if regulatory goals (health, safety, and welfare) are achieved, or to oversee costs and benefits, unforeseen side-effects, and efficiency.

The project will use state-of-the-art studies to examine the building regulatory system and the manner in which its various component parts operate and interact on the built environment and the nation's builders. From these evaluations and in conjunction with other authorities, support for specific recommendations for improvement will be developed.

Technology for Building Standards & Codes

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Sponsor: National Bureau of Standards

This project focuses on the development of methods, guidelines, and computer aids for the formulation of specifications, standards, and codes along with prototype applications of technology. The approach will include tasks to be carried out between various universities as well as engaging the services of private consulting architectural and engineering firms and model code groups and standards-generating organizations. Opportunities to participate in standard writing projects at CBT will be accepted to provide case studies for the application of the methods and for the exposure to new users. Related projects funded by other agencies, such as the "Formulation and Expression of Seismic Design Provisions," will be coordinated with this project to achieve overall program objectives in an efficient manner. In the end, the project will reduce dangerous and expensive errors by making the meaning of standards clearer. It will also speed formulation of improved standards by assuring attainment of the intended scope and by clearly expressing technical improvement.

International Standards Activities

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Sponsor: National Bureau of Standards

This ongoing CBT research activity regarding international activities in building standards and regulations has revealed the two-way impact of the U.S. joining the metric building world. This U.S. action is closing the last link in a technical communication chain, best exemplified by standards, associated with the world-wide movement to SI. As revealed by this research project, the U.S. building community now has many new opportunities to participate, meaningfully, in international standards activities of importance to manufacturers designers, regulators and building owners. This research activity has enabled the CBT to observe and participate in the building standards activities of the International

Organization for Standardization (ISO) and the Working Party on the Building Industry of the United Nation Economic Commission of Europe (UN/ECE). Both groups are cooperatively engaged in a large international standardization project aimed at harmonizing national building regulation through the application of the performance concept.

Out of this research project will come recommendations for a dimensionally coordinated U.S. approach to metric, performance-based building regulations whose national applications have a built-in international compatibility.

Metrication and Dimensional Coordination

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Sponsor: National Bureau of Standards

The United States is the last of the major industrialized nations to embark on the change to a metric system of measurement. CBT is providing support to the construction community and input to rewriting the technical data base of the community. CBT will be involved in the investigation and analysis of optimum industry-wide solutions to metric dimensional coordination. Also, we will assist the industry in developing a system of dimensional coordination appropriate to the construction community. This will be encouraged by a continuation of the secretariat role on the Design, Codes and Standards and the Products Sector of the Construction Industries Coordinating Committee, ANMC. A series of technical documents will be developed and disseminated to both private and public organizations. Draft standards will be developed and processed through the voluntary consensus process.

Metrication Consultancy

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Building Economics and Regulatory Technology Division

Sponsor: National Bureau of Standards

The Metric Conversion Act of 1975 called for the appointment of a Metric Board to coordinate our conversion to metric measurement. It is likely the Metric Board, when appointed, will look to CBT for technical assistance and support. Mr. Hans Milton, Assistant Secretary, Housing and Community Development of the Australian Government, was instrumental in the metric conversion of Australia's building industry. For that reason, Mr. Milton joined the CBT staff. During his stay at NBS, he began development of a series of draft standards on metric dimensional coordination, and on the determination and selection of preferred numerical values in conjunction with metric conversion. As a result of this work, several technical publications in the metric and dimensional coordination subject area are planned: "Metric Dimensional Coordination" (several documents); and "Preferred Numerical Values for Building Codes and Standards." In addition, NBS, through Mr. Milton, will provide input to metric technical reference documents (AIA, ASHARE, and others). Likewise, Technical Note 938, *Recommended Practice for the Use of Metric (SI) Units in Building Design and Construction,* is being

processed through the voluntary consensus procedure to become a national standard.

Development of Preferred Metric Values

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Building Economics and Regulatory Technology Division

Sponsor: National Bureau of Standards

The American building community is at the threshold of planning for conversion to the metric system of measurement. Critical to this plan must be the review and conversion of the data base upon which the building community largely depends. This undertaking can be termed the metrication of building standards and codes. It can be more explicitly described as the conversion, rounding, and rationalization of numerical values and dimensions in building specifications, standards, and codes. An urgent and important task is to develop a general method to assist decision-makers in effective, reliable, and technically sound substitution of metric values and dimensions for customary values in building specifications.

The major task of the work is to develop the method for use in the metrication of building specifications, standards, codes, and reference data through the simple and rational analysis of potential preferred metric replacement values related to the variance from the customary value. This mathematical method will not select new values, it will simply organize them. It will assist in the selection of new values through organization and accomplishment of the following: (1) the rational and comprehensive examination of a range of alternative values; (2) the listing of the most preferred numerical values in the metric environment; and (3) the demonstration, in percentage terms and customary units, of the quantitative changes associated with preferred metric values.

Through this project, metric values of equal or greater numerical simplicity in building specifications, standards, and codes will be achieved, thus ensuring that calculations and verifications are not made more difficult through metrication.

Participation in ANSI A119, Mobile Homes and Recreation Vehicles

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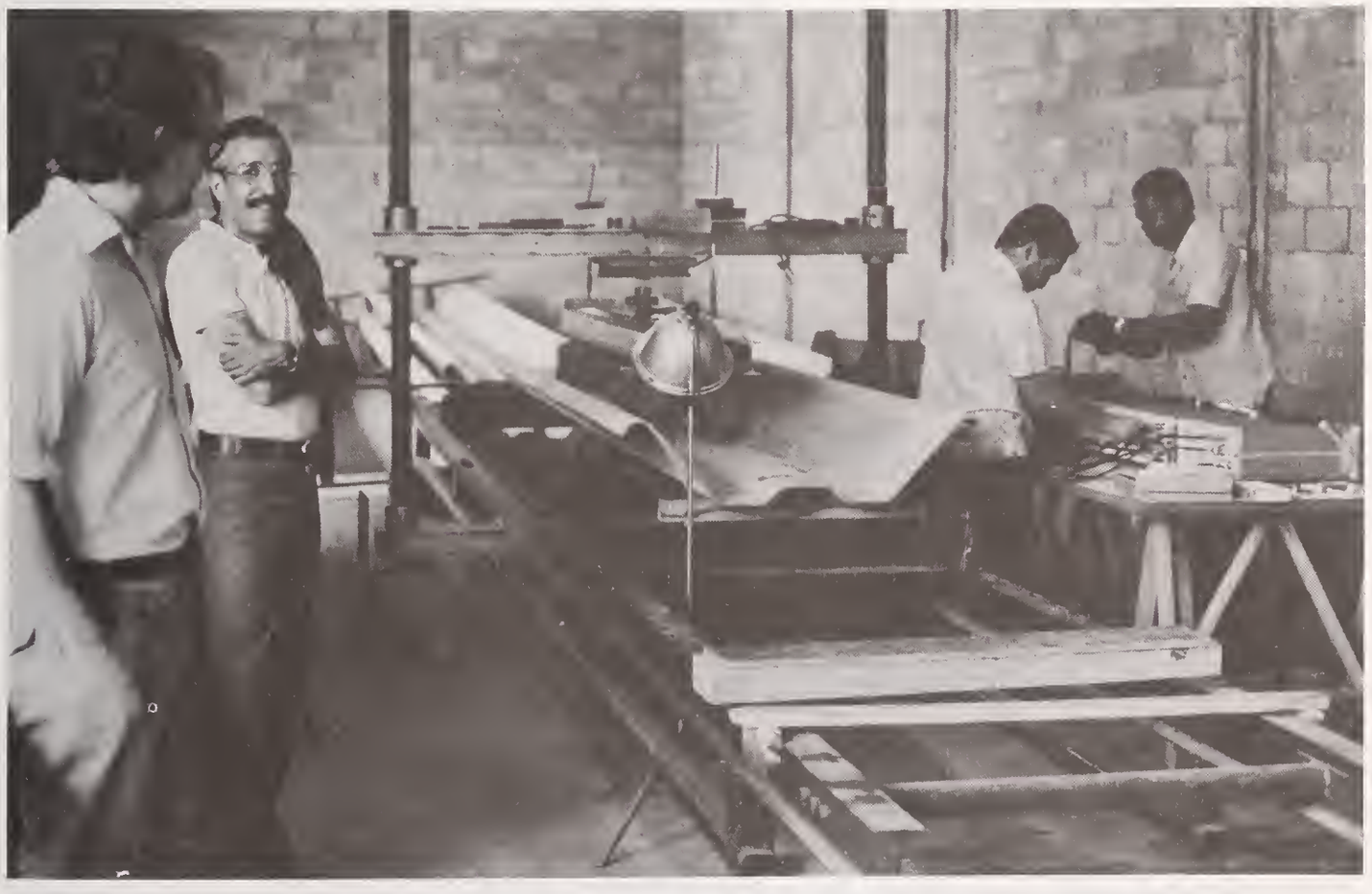
Building Economics and Regulatory Technology Division

Sponsor: Department of Housing and Urban Development

This project aims at putting the results of CBT mobile home research into use through the Federal Mobile Home Standards and the voluntary consensus process (ANSI Standard A119). The significant role of CBT in the mobile home standards development process is recognized by mobile home industrial groups, Federal agencies (HUD, VA), and mobile home standards development groups. While it is gaining recognition for its research effort in the mobile home area, maximum impact from the project will be gained by transmitting technical data to the building community. But the real benefit will be the reduction of loss of life in mobile homes due to fire and wind, reduction of energy use in heating and cooling, and in general improvement in the living environment of mobile home occupants.

Housing & Building Technology



Brazilians applying materials durability knowledge gained while under research training at NBS.

Federal Building Technology

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Sponsor: National Bureau of Standards

The Federal Building Technology program serves as an effective coordinating link between the CBT and the Federal Construction agencies. The program addresses many critical issues and concerns of the Federal sector involved in building construction. To this end, the project sponsored nine Federal agency workshops last year. Special workshops were held on indoor air-quality control. CBT also took part in the Federal Construction Council (FCC) by publishing the FCC Newletters—"General Newletter" and "Energy Newsletters"—and the Engineering Studies List, and by coordinating FCC committee appointments. CBT also serves as the secretariat of the Federal Agency Metric Construction Panel of the Interagency Committee on Standards Policy. These and other similar activities—including nine more one-day Federal workshops—will continue in 1978.

Housing Technology

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Building Economics and Regulatory
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Sponsor: National Bureau of Standards

The U.S. population has a continuing need for adequate housing at reasonable cost. One approach to achieving this objective is to focus new technologies and research on housing problems to reduce costs and improve the performance of housing systems and components. Government-sponsored research in the field of building technology is both diverse and divergent. More than a dozen Federal agencies carry out research in this area. In spite of, or perhaps because of, the enormous amount of information being generated, it is extremely difficult to keep current with all this research and to coordinate related efforts.

This project is intended to establish and maintain contact with the major segments of the private housing industry as well as Federal, state, and local government housing agencies. The major objective of those contacts is to identify and define housing problems whose solution can be achieved by the application of research.

Architectural Barriers to the Handicapped

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Sponsor: Architectural and
Transportation Barrier Compliance Board

The Architectural Barriers Act of 1968 and the Rehabilitation Act of 1973 provided for a barrier-free environment for those with motor or sensory handicaps. However, the present collection of rules and recommendations promulgated by nine different Federal agencies does not adequately address this problem. In general, there does not exist an adequate technical basis for rational, performance-oriented Federal standards that will assure the usability of buildings by the handicapped.

Under this project an NBS "Research Plan Development Team" will be formed, including representatives from a member of CBT/NBS operating units and consultants. Team members will individually become familiar with the existing standards and the problems of the handicapped as viewed from their own disciplines' perspective. Team meetings will be scheduled

on a regular basis to develop a comprehensive research plan.

At the sponsor's request, a special review of the literature relating to "flooring materials as a barrier to wheelchairs" will be completed. A research plan will then be developed that identifies major barriers to the handicapped, and proposes research activities to develop a technical basis for performance standards.

Research findings will be disseminated to appropriate standards organizations and Federal agencies that have statutory responsibility for providing a barrier-free environment. The project output is an initial step in a process which will lead to adequate, uniform standards to insure barrier-free access to buildings to the handicapped.

Housing Evaluation Methodology

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Environmental Design Research Division

Sponsor: National Bureau of Standards

This project will provide evaluation instruments and a housing research design method suitable for educational and research purposes to encourage housing research and to increase its methodological sophistication. Given the high cost of instrument and research design development and the scarcity of published examples of housing questionnaires and of housing research design models and procedures, the value of such a published report is underscored.

Instrument evaluation includes a revision of a prototype housing questionnaire to increase its applicability and ease of use. Additional instruments, used in an evaluation of federally-sponsored housing, will be included and experiences will be summarized. Research data, not previously available, will be included to illustrate item coding as well as to indicate research results. Practical discussions of questionnaire development, survey research principles, and research design models will be included allowing others to incorporate or build on our experiences.

Planned products include the project report plus two articles suitable for publication in a technical journal. The articles will focus on the research design model and the field study based on it. These products will be of educational value to students and of direct practical significance to researchers and others in the housing design, construction, and management fields.

Building Technology Information

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Headquarters

Sponsor: National Bureau of Standards

Information is the Center's ultimate product. This project is aimed at effective delivery of that product through skillful dissemination techniques and an understanding of the information needed by the building community. To this end, the Center has established a multidimensional information program. It broadcasts research findings, answers specific inquiries, and interacts with the building community through joint activities with building groups, tours and conferences at the Bureau, and meetings and conventions of building

organizations. All this permits a two-way information program in meeting the needs of the building community's research, policy-making, application, and consuming sectors. Recent products were summaries of all the Center's research activities: *Building Technology Project Summaries; Building Technology Publications,* a cumulative listing of the Center's publications; brochures on CBT building research activities; and a draft report scheduled for printing in late 1978, *Building Research at the National Bureau of Standards, 1968-1974.*

In addition, this project provides on-going data acquisition and data analysis capabilities and interfaces with several CBT laboratories for the purposes of laboratory automation, automatic data processing and display, and the processing of management information. In FY76 the CBT plumbing laboratory was connected with the CBT mini-computer and currently the vision laboratory is being tied into the CBT computer.

IPT/NBS Cooperative Program

Thomas K. Faison
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Building Economics and Regulatory Technology Division

Sponsor: Instituto De Pesquisas Tecnogicas, Brazil

As part of an overall Memorandum of Understanding between NBS and the Instituto De Pesquisas Tecnogicas (IPT) of Sao Paulo, Brazil, CBT provides opportunities for the staff of IPT to gain training through direct participation in on-going projects within CBT. CBT gains the support provided by the trainee during the assignment at NBS. Further opportunities are made available to the trainee to experience activities outside CBT, such as: visits to Underwriter Laboratories, participation in professional society activities (ASME, ASHRAE), and field training with building code groups.

During the past year, training has been provided in the areas of plumbing and electrical systems engineering. Currently there are trainees in materials durability and thermal engineering; additional trainees in material properties will be included in the Program.

International Building Research

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Center for Building Technology Headquarters

Sponsor: National Bureau of Standards

This project provides a forum for researchers from CBT and foreign research organizations to exchange information, help in coordinating their research activities, and host tours of CBT facilities. The project responds to foreign requests for technical information on building technology, supports complementary building research activities, provides a mechanism to exchange technical staff, offers a means to participate in international conferences as members in international organizations, and furnishes technical assistance to developing countries.

CBT has conducted international programs with Brazil, Canada, France, Japan, Philippines, England, Soviet Union, Spain, Indonesia, and other countries, and has served on numerous international panels (such as the International Council for Building Research Studies and

Documentation, International Organization for Standards, the International Union of Testing and Research Laboratories for Materials and Structures, and the International Institute of Refrigeration). This year such work will be expanded to cover cooperative research with Poland and Israel, among other nations. The Center also publishes an annual NBSIR document, *International Research—Survey of CBT's International Programs.*

Classification Committee Staff Support

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Environmental Design Research Division

Sponsor: National Bureau of Standards

This project provides staff support to the steering committee assembled to select a universal building classification scheme. The support will aid the committee in the identification of current activities directed toward the establishment of uniform classifications and their potential impact on the building process. In addition, aid in determining the technical feasibility of developing a single classification and the factors inhibiting its potential adoption will be addressed. The benefit of such a classification scheme: a way of looking at buildings that at once covers fire safety, energy, economic, and other factors. In other words, a holistic approach to building regulation.

Technical Support to the Tri-Services Committee

Robert T. Mathey
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Structures and Materials Division

Sponsor: Department of Defense, Tri-Services Committee

This project provides technical and scientific support and consultative services on building materials and systems as required by Tri-Services. The work will include carrying out laboratory tests and evaluations in the solution of building problems as well as field investigations. Recommendations will be made with regard to the selection of materials and systems and their application or operation.

Today, the Tri-Services are experiencing serious building-related problems. They also are interested in using new materials and systems for which standards and criteria are not available. The solutions to problems and information on new materials and systems will also benefit other governmental agencies and the private sector by eliminating or reducing unanticipated early building materials and systems failures.

HUD Studies

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Sponsor: Department of Housing and Urban Development

CBT will perform tasks for a wide variety of HUD research needs throughout fiscal year 1978. Each task shall be performed within certain prescribed time limits and will cover such areas as: (1) durability testing and criteria, (2) hazard determination, and (3) building technology assessments. Specific tasks may encompass such examples as conducting performance tests on questionable materials or assemblies, a racking test on a panel wall, testing soil for leaching of termite poison,

making air-quality tests in homes where asbestos materials have been used, measuring the capability of an *in-situ* brick testing device, writing a state-of-the-art report on plumbing trees, and developing criteria for hallway width; such were the studies completed in the recent past.

CBT's involvement in this work is a continuation of its traditional role of support to other government agencies. The unique characteristic of this project is that it will give both HUD and CBT the capability of responding quickly to those day-to-day problems that require immediate technical attention and action.

Design and Construction Technology Application Program (DAC/TAP)

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Headquarters

Sponsor: National Bureau of Standards

The objective of this program is to improve building design and construction practices by identifying researchable problems in cooperation with those who design and build buildings, by assisting in the formulation of responsive research projects and programs, by delivering usable technical information to the building design and construction communities, by participating in cooperative technology application demonstrations and by evaluating the impact of new technology. The approach is based on close interaction with the design and construction communities directly and through their professional and trade organizations.

Design and construction community input will be provided to research project leaders for the precise definition of the research problem to be answered and as a continuing resource during the research activities. Research findings and other technical information will be converted as necessary into forms usable by the design and construction communities. Cooperative efforts will be mounted with professional and trade organizations in the building design and construction communities to track and to evaluate the effectiveness of the problem identification and information delivery process, the method of application by the design and construction communities, and the impact of using newly applied

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