Building Technology Project Summaries 1979

NBS SP 446-3

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The Center for Building Technology provides the technical and scientific bases for criteria and standards that improve the usefulness, safety and economy of buildings while conserving building materials and energy. The Center's activities support building technology programs of the Federal, State and local governments; assists design professions, building officials and the research community by developing design criteria that improve buildings; and assists manufacturers of building products by developing criteria for evaluating innovative building materials. This report summarizes the Center's projects for calendar years 1978-79.It enables individuals to get a clear impression of CBT research activities.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)* Building research; building technology; criteria; codes; project summaries; standards; technical bases.

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Foreword

The Center for Building Technology's (CBT) mission is to increase the usefulness, safety, and economy of buildings through the advancement of building technology and its application to the improvement of building practices. CBT's research activities support the building technology programs of Federal, state, and local governments; 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 materials, components and systems.

Ultimately, each project at the Center aims to provide improved knowledge, in usable form, to the building community. Typical CBT activities include: investigations of failures, such as the Willow Island cooling tower accident, to determine causes and needs for improved practices; improvements of measurement techniques such as development of accurate equipment to measure the performance of thick insulation; defining characteristics of building performance such as human response to time-varying noise; and developing consistent methods for comparing benefits and costs such as life-cycle cost approaches for selecting optimal energy retrofit measures. All these activities are conducted in cooperation with other organizations in the building community that participate in the studies or are affected by the results.

NBS/CBT does not promulgate building codes or standards. CBT provides an objective source of technical information for national consensus standards and model code organizations. Close cooperation with these groups leads to standard practices that meet the needs of the regulatory authorities of state and local governments. Research providing the knowledge for these standard practices is conducted in cooperation with university and industry research laboratories.

This report summarizes CBT's research for 1978-1979. Each summary lists the project title, its progress, point of contact within CBT, and sponsor.

The reader is encouraged to review two companion documents: 1) NBS Special Publication 439, *The Center for Building Technology: A Perspective,* which presents the Center's approach to building research and its facilities; and 2) Special Publication *457, Building Technology Publications,* and its supplements.

The summaries presented in this report are arranged according to the programs and tasks that comprise the scope of work at CBT. These categories were selected to group like projects—not to reflect the structure of the Center, which is shown on page x.

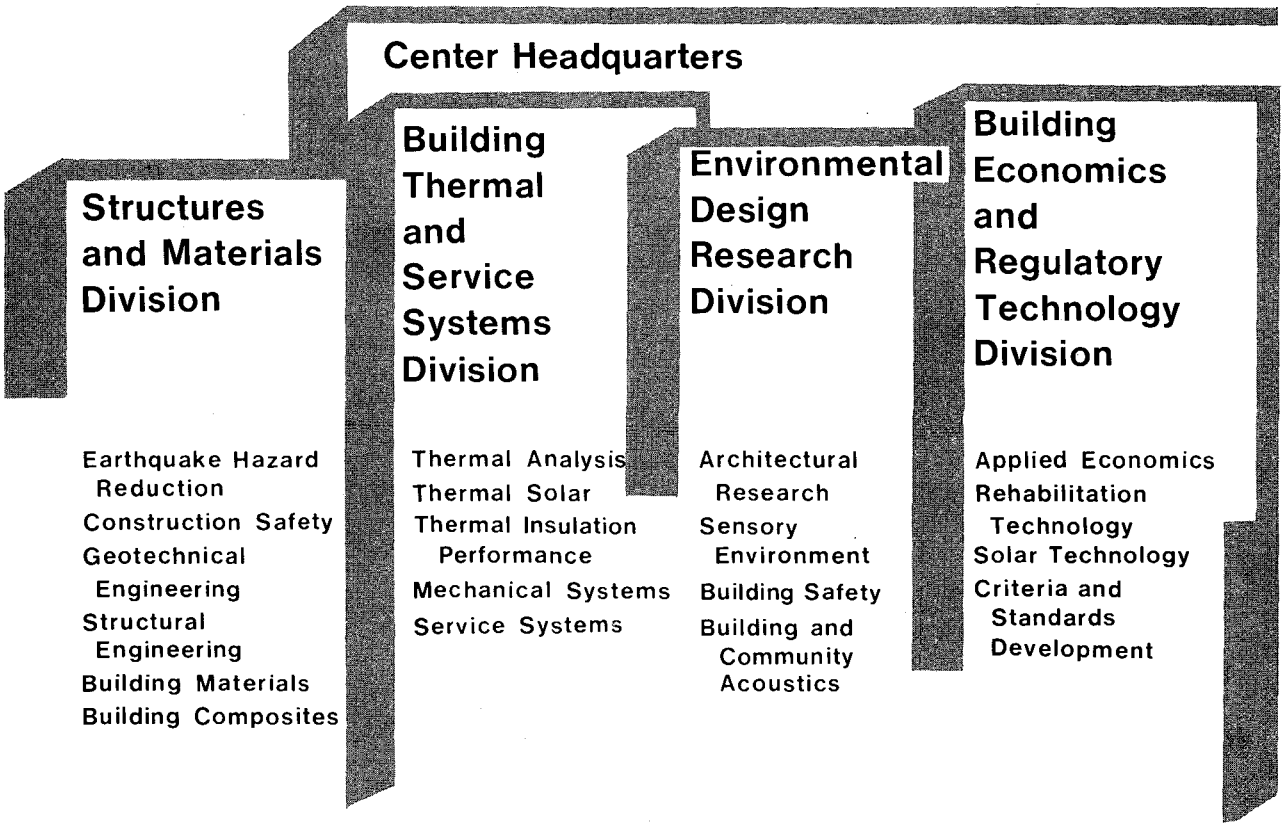
Contents

Abbreviations Used in the Text

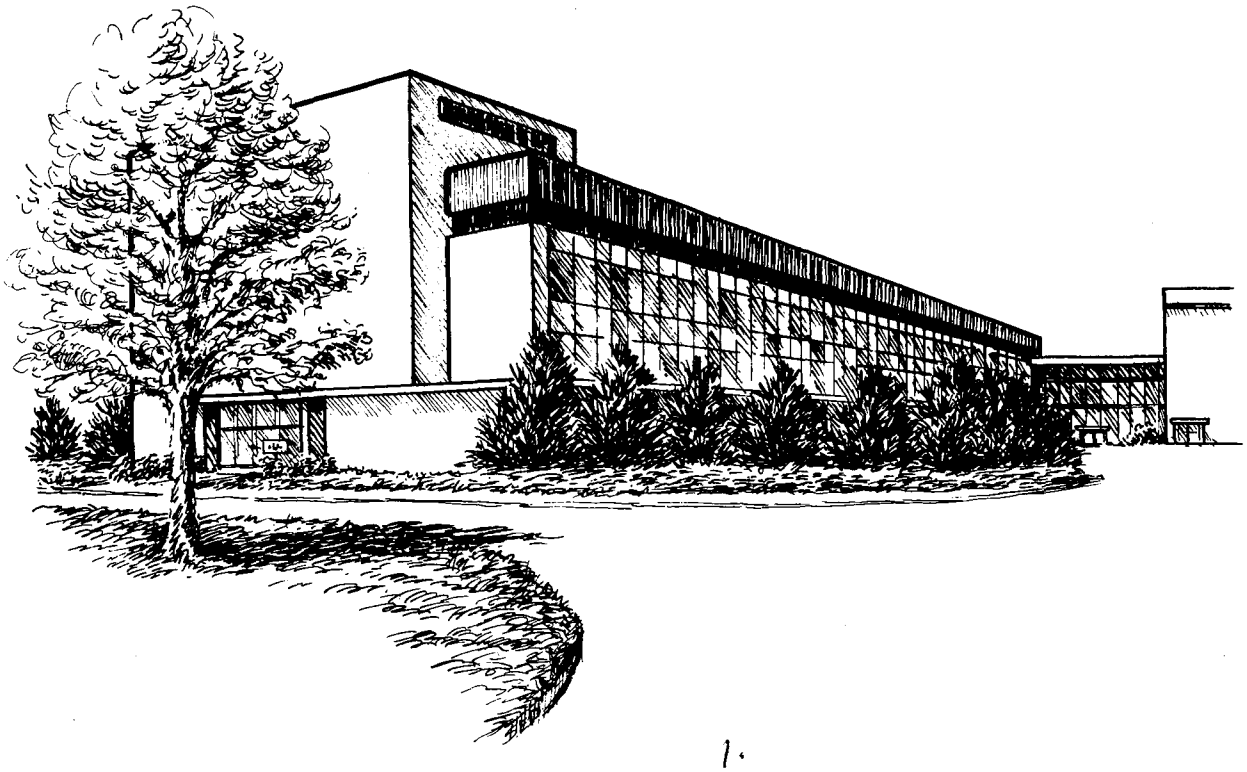
ACF	Area Cost Factors
AID	Agency for International Development
ACI	American Concrete Institute
AIA	American Institute of Architects
ANMC	American National Metrication Council
ANSI	American National Standards Institute
ARI	American Research Institute
ASPE	American Society of Plumbing Engineers
ASSE	American Society of Sanitary Engineers
ASTM	American Society for Testing and Materials
ASHRAE	American Society for Heating, Refrigeration, and Air-Conditioning Engineers
ASME	American Society for Mechanical Engineers
BECC	Building Energy Conservation Criteria
BLAST	Building Loads Analysis and Systems Thermodynamics
BFIRES	A Computer Program Dealing With Human
BOCA	Building Officials and Code Administrators International, Inc.
CBT	Center for Building Technology
CFR	Center for Fire Research
CIB	International Council for Building Research, Studies, and Documentation
CSA	Community Services Administration
CPSC	Consumer Product Safety Commission
DoE	Department of Energy
EDA	Economic Development Administration
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FCC	Federal Construction Council
FERC	Federal Energy Regulatory Commission
FHA	Farmers Home Administration
FHWA	Federal Highway Administration
FIRL	Franklin Institute Research Laboratories
GSA	General Services Administration
HUD	Department of Housing and Urban Development
HVAC	Heating, Ventilation, and Air-Conditioning
ICBO	International Conference of Building Officials
IEEE	Institute of Electrical and Electronic Engineers
ISO	International Standards Organization
LBL	Lawrence Berkeley Laboratory
LCC	Life-Cycle Costing
LNG	Liquid Natural Gas
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	Nondestructive Evaluation

NEC	National Electric Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NIBS	National Institute of Building Sciences
NIOSH	National Institutes of Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRC	National Research Council (Canada)
NSF	National Science Foundation
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
SPT	Standard Penetration Tests
SRM	Standard Reference Materials
UF	Urea-Formaldehyde
USGS	United States Geological Survey
USNC/CIB	United States National Committee/International Council for Building Research, Studies, and Documentation
VA	Veterans Administration

Center for Building Technology



Energy Conservation in Buildings



Building Infiltration Evaluation

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Building Thermal and Service Systems Division

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. Under this project, the NBS Administration Building is being instrumented to measure air exchange by using SF_6 tracer gas. Wind direction and velocity, as well as inside and outside temperature data, are simultaneously taken. Provisions are also being made to operate the building in its normal mode as well as with all of its air intakes and exhausts closed. Inside and outside pressure differences will be measured in the different operating modes. Also fan pressurization measurements are planned to determine the flow resistance of the building envelope. The data will be used to measure the air-exchange behavior of high-rise buildings. Measurements on at least one other large building will then be made.

Tracer Gas System

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Sponsor: Department of Energy

Ventilation and air infiltration is an important area to be considered for energy savings. The improved capability for measuring air flow that this project will provide, through new equipment for sensing tracer gases, is a major component in understanding this phenomenon.

Mobile Blower Systems

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Sponsor: Department of Energy

Fan pressurization-evacuation procedures have come into wide use for determining the comparative tightness of single-family homes. Although it is much more difficult to do this with large buildings, this information is important in analyzing and reducing air leakage. The systems designed and built under this project will consist of a fan capable of delivering at least 15,000 cfm at 0.5 in. W.G. static pressure and a method of measuring fan flow rate. The system will be temporarily sealed in outside doorways, and inside-outside pressure difference will be measured as the blower introduces or extracts air at measured flow rates. A single flow system will be obtained first to develop testing techniques. This will make it possible to test larger buildings than we have tested previously. Based on this experience, additional systems will be obtained, depending on the size of future buildings to be tested.

Energy Analysis: Norris Cotton Building

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Sponsor: Department of Energy

GSA's Norris Cotton Federal Office Building in Manchester, New Hampshire, has been designed to demonstrate a number of energy-saving concepts. For this reason, it uses a variety of equipment, such as heat pumps, modular boilers, and engine/generator with waste heat recovery, solar collectors, liquid thermal storage, and special lighting. Exterior walls are of heavy masonry construction with an outer insulating layer to create a "thermal flywheel" thereby reducing peak heating and cooling loads. The windows are double-glazed and occupy a relatively small fraction of the exterior facade. Fin-like granite panels surround the windows and are fixed in a position that reflects in sunlight during winter, blocks out sunlight in summer, and breaks up strong winds. Of the building's seven floors, no two are the same. Each one has some variation in its mechanical equipment, lighting, and/or window arrangement. Employing several different energy saving concepts will, of course, have value only if each is assessed individually for its effectiveness.

A computer data-acquisition system has been installed on site that senses critical temperatures, fluid flows, and electrical power throughout the building and records this information on magnetic tape. These tapes are then sent to CBT where they are processed by a UNIVAC 1108 computer. The output will be a breakdown of energy usage within the building. Also, computer simulations will be performed for the purpose of evaluating the effectiveness of the equipment as it is currently operated. This simulation program will also be used to study the effects of system modifications.

User Acceptance: Norris Cotton Building

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Sponsor: Department of Energy

Under this project, selective interviewing was carried out with individuals in various agencies prior to their move to the Norris Cotton Building, Manchester, NH. Two extensive questionnaires were administered in the spring, about five months after occupancy. A second similar questionnaire was administered in the late fall, about eight months after the first one. Response percentages for specific questions have been calculated and reported in two letter reports (February 1978 and March 1978). Of greater importance than the response percentages, however, are the floor-by-floor comparisons to determine if there are significant differences in the responses of occupants on different floors (different floors have different design features). Chi-square analyses will be performed to identify which differences are statistically significant. In addition, the results of two questionnaires will be compared to determine changes in occupant opinion over time and responses to varying weather conditions.

Part-Load Efficiency

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Building Thermal and Service Systems Division

Sponsor: Department of Energy

Considerable energy waste is known to result from mismatching and oversizing (safety-factor padding) for mechanical equipment in large HVAC systems.

This practice has come about, in part, because of the lack of published data on the equipment's part-load or dynamic-load characteristics.

In this project, CBT will be the central coordinator of all major equipment part-load data. This 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 be a computer program subroutine. The methods of data generation include searching and transcribing from existing literature, theoretical modeling, laboratory or factory experiment, and field evaluation.

To date, a listing of the major equipment items and a determination of the status of part-load performance data has been developed for equipment now being considered. Where the data are known, the best source of information has been identified. Where the data are unknown, the best method of generating the data has been recommended. This year the focus is on the completion of the simulation codes for centrifugal-compressor and reciprocating-compressor chilled water systems.

Central Air Conditioner Test Procedures

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Sponsor: Department of Energy

This year, CBT research on central air conditioners will be aimed at determining whether the present test procedure can be simplified. Experimental laboratory work will be carried out on the effect of different design features (thermal expansion device, capillary tube, fixed orifice, etc.) on the part-load and seasonal performance of residential central air conditioning equipment. It is hoped that research will lead to the development of degradation coefficients (or "enhancement factors") that can be assigned in accordance with the different design features possessed by a unit. Work will also begin on a central air conditioner computer "model" that could lead to a considerable reduction in the amount of testing required by manufacturers and also make the job of verifying their compliance considerably easier. A draft report summarizing our recommendations on minimum performance standards for central air conditioners will be sent to DoE.

Heat Pump Test Procedures

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Sponsor: Department of Energy

During this year, the CBT work on heat pumps will involve verification of the proposed test procedure and its extension to cover water-source units and units employing gas or oil-fired furnaces to supply supplemental heat. Verification will involve comparing predicted seasonal performance results with data collected by a leading electrical utility company in the Chicago area. A laboratory study will be performed on a

water-source heat pump to evaluate its performance and to determine the best method for testing and rating such devices. The test procedure will be broadened to cover "hybrid" systems that use gas or oil, instead of electricity, as the source of supplemental heat. Work will begin on developing recommendations for the Department of Energy on minimum performance standards for electrical motor-driven residential heat pumps. Draft test procedures for water-source heat pumps and "hybrid" heat-pump systems will be developed.

Innovative Heat Pumps—Modified Temperature Bin Method

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Sponsor: Department of Energy

The present method of calculating the seasonal energy efficiency ratio (SEER) and seasonal energy consumption of residential heat pump equipment is based on a temperature bin method. A basic assumption in this method is that residential building cooling loads are solely a function of the outdoor dry-bulb temperature. In this project, the BLAST computer program will be used to model and predict hourly residential heating and cooling loads. Several residential buildings 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 heat and cooling loads. The correlation will then be used to develop a modified temperature bin procedure that 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.

The modified temperature bin calculation procedure will predict 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 be kept simple, not requiring the use of a computer.

Innovative Heat Pumps—Test Method For Engine-Driven Heat Pumps

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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 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 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 analytical results obtained on engine-driven Rankine cycle heat pumps by other research 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.) that are potentially suitable for heat-pump applications. This information will then be integrated with: CBT experience and test results on Stirling cycle engine and diesel-engine-driven heat pumps; CBT test and rating procedures on electric-driven Rankine-cycle heat pumps and other heating and cooling devices; and 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. The test procedure will be available for industrial review by the end of this fiscal year.

Furnace Test Procedures

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Sponsor: Department of Energy

CBT is in the process of developing its recommendations to DoE on minimum furnace performance standards. In addition, NBS will work with DoE-supported contractors to develop technical and economic information relating to minimum standards for furnaces and boilers. The NBS-developed computer programs DEPAF and DEPAB will be used to carry out much of the technical evaluation required as part of this task. In the area of test procedure refinement, a computer model will be developed to describe the performance of a furnace or boiler located in either an "unheated" basement, a heated space, and "indoor closet" or outside. Recommendations will also be made to DoE on how to expand the present test procedure to cover dampers that open and close by thermal expansion and contraction. A draft computer code covering installation of furnaces and boilers in various applications will be developed. A report summarizing how thermal vent dampers should be tested will be produced. A draft report will be sent to DoE covering recommendations on minimum furnace/boiler performance standards.

Computerized Climate Data

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Sponsor: Department of Energy

Building energy-load programs such as NBSLD and DoE-1 compute on an hour-by-hour basis using weather data tapes containing observations that are typically collected at major airports, and are available for a limited number of locations in the U.S. Since meso- and micro-climates may differ widely within a region that contains only one hourly collection station, the current practice of using that station's weather data to predict the energy

consumption of a building may cause substantial error. The magnitude of this error exceeds the error inherent in existing load programs, and has an adverse effect on energy efficient building designs.

This program will develop an algorithm compatible with DoE-1 to mathematically transform hourly weather data from meteorological stations to the microclimate of the building site. The climate variable—temperature, humidity, wind velocity, and solar radiation—will be considered. The influences of topography, surface features, surrounding buildings, and vegetation will be included in the transform. The algorithm will take standard NOAA-format weather tapes as input, and with a minimum of description of the topography and surroundings of the building site, perform the conversion.

Technical Support of BECC

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Building Thermal and Services Systems Division

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 research-based DoE/NBS Building Energy Conservation Criteria (BECC) program.

The products of this activity frequently take the form of written recommendations and comments on 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. As DoE requirements become defined, this effort will support state energy development plans under P.L. 94-163, and development of improved energy performance criteria.

Building Energy Performance Criteria

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Sponsor: Department of Energy

Recent Federal programs to regulate energy use at the design stage of new buildings have pushed toward the elevation of performance standards to the whole building level. Preliminary research for the development of such building energy performance standards has been based largely on statistical analysis of calculated building design energy requirements without specific regard to the performance of the building components themselves. However, it appears that component energy performance standards will continue to play an active role in the regulation of building designs as an alternative path to building energy conservation. As a result, this project will provide a methodology for the whole building level. A side benefit of such a method is the assurance that the two paths to building design are consistent and complementary.

Use of Daylighting in Electric Energy Conservation

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Sponsor: Department of Energy and Tri-Services Committee

Since lighting constitutes 5 percent of the total U.S. energy demand, the use of daylight rather than electricity for lighting is an important step in energy independence. This project will develop energy conservation guidelines with respect to the use of daylighting by conducting several laboratory experiments to study lighting and to evaluate various daylight control devices. Window management techniques will also be studied for their contribution to energy conservation. Since existing daylight calculation methods are very complex, often involving large computer programs, this project will also concentrate on more simplified procedures, suitable for making annual energy trade-offs.

Simplified Load Calculation for Project Home Audit

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Sponsor: Department of Energy

The objective of this effort is the documentation and validation of a simplified heating and cooling load program for Project Home Audit, a program to assist homeowners in evaluating the effectiveness of energy conservation options. NBSLD will be modified to use average monthly temperature and average daily total solar radiation for calculating the energy requirements of single-family detached homes based upon twelve mean days, each representing a month of the year. CBT has developed 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 metered energy consumption values of actual houses for a few selected locations in the country.

Building User Audits

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Environmental Design Research Division

Sponsor: National Bureau of Standards

Many audits of energy use in buildings are now under way, and more are being planned. These activities are designed to provide baseline data describing energy use associated with selected building parameters. The usefulness of these data depend upon a number of assumptions about the comparability of the data and usage patterns. These assumptions are questionable. As to the comparability of data, standardized data collection techniques are not available for developing energy audits.

The present research activity will focus on a better understanding of usage patterns as they affect the validity of energy audit information. Once the relevant usage data are identified and quantified, they can be factored into an audit procedure, by removing this "error" term. Moreover, as we learn more about how operations and user actions influence energy use, owners, operators, and users can begin to take steps to influence energy savings.

Building Thermal Load Program

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Sponsor: National Bureau of Standards

This project will update the NBSLD computer program by improving existing subroutines and adding a few new ones. Routines to be added are the thermal comfort index, daylighting, whole house-fan, and simple heating/cooling equipment simulation. The user manual will also be improved to minimize input interpretation errors.

Energy Calculation Review

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Sponsor: Department of Energy

National emphasis on improved building designs for energy conservation has resulted in numerous energy consumption analysis procedures, both manual and computer-based. The increased proliferation of these energy analysis procedures and programs is resulting in confusion among public officials, architect-engineer firms, and private citizens, who rely on energy calculations to select energy saving features for their buildings.

The objective of this effort is a compilation of the technical details of existing energy calculation procedures to assist DoE in disseminating the information, and the establishment of guidelines for manual energy calculation procedures suitable for use by small A/E consulting firms.

Second Law Efficiency Study

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Sponsor: Department of Energy

The 1978 National Energy Conservation Policy Act (Section 683) states: "The Secretary of Energy in consultation with the Director of the National Bureau of Standards . . . shall conduct a study of relevance to energy conservation programs of the use of the concept of energy efficiency as being the ratio of the minimum available work necessary for accomplishing a given task to the available work in the actual fuel used to accomplish that task." This definition for efficiency is arrived at by applying the second law of thermodynamics to a thermal system rather than the usual first law. It has the effect of "normalizing" the various energy sources to the same baseline for evaluation. It also tends to identify exactly where the inefficiencies of a process exist. It is Congress' intent to see where it might be beneficial and practical to apply this second law efficiency as a measure for energy conservation rather than the traditional first law efficiency. Under this project, a study of the second law will be carried out by a private contractor. Its results will be transmitted to Congress after analysis by CBT.

Thermal Encapsulation of Electrical Wiring

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Sponsor: Department of Energy

When ceiling and cavity walls of residential buildings are retrofitted with thermal insulation, electrical branch wiring circuits become surrounded with thermal insulation. When these branch wiring circuits carry rated current, the wiring temperature exceeds the maximum service temperature specified in the National Electrical Code. The problem becomes particularly serious in attics when several branch wiring circuits run adjacent to each other and are covered with a thick covering of thermal insulation. Temperatures may reach as high as 150 °C, which significantly exceeds the maximum service temperature for residential branch wire. This study will focus on solutions to eliminate overheating of residential branch wiring circuits due to the addition of retrofit insulation. Solutions examined will include derating the ampacity of branch circuits, raising branch wiring above thermal insulation, and placing wiring in contact with wood structural members which may reduce wire temperature through a heat-sinking effect.

Energy Retrofit: Insulation and Wiring

Lawrence S. Galowin
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Building Thermal and Service Systems Division

Sponsor: Department of Energy

This project will conduct laboratory tests to establish tables of allowable thermal blanketing over wiring of various sizes at their peak ampacity ratings with several insulation materials. Acceptable installation practices to provide thermal release paths for thermal insulation will be determined. CBT will also study the ability of studs, joists, and gypsum to reduce wire temperatures. The outcome of this work will be safety criteria for use by DoE.

Inspection of Wiring Under Insulation

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Sponsor: Department of Energy

Under this project, the electrical wiring of some 400 low-income homes (in the CSA weatherization demonstration) will be inspected. CBT is developing inspection procedures for this activity for three levels of inspection: the layman CSA local program person; a licensed electrician or electrical inspector; and an in-depth evaluation by CBT personnel. Based on the experience with the three inspection levels in the CSA demonstration, CBT will develop inspection procedures and checklists for use in the program. The final procedures will be coordinated with national organizations such as NFPA.

Retrofit Guidelines

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Sponsor: Department of Energy

This project will support DoE in the residential conservation area of the National Energy Act. The purpose is to assure that the selection, quality, and insulation of various retrofit measures is cost-effective, safe, and energy saving. The work will center on five tasks: development of a method for setting priorities for retrofit measures; development of standards for installation practices; assistance to DoE in identifying, revising, and establishing criteria for retrofit materials and products; investigation of electrical hazards resulting from placing thermal insulation around and over existing electrical wiring; and preparation of procedures and checklists for the inspection of electrical wiring in conjunction with the installation of thermal insulation.

Ranking of Measures for Energy Retrofit

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Sponsor: Department of Energy

A computerized methodology for estimating the dollar energy savings from a number of retrofit measures has been developed. This methodology ranks the measures in terms of life-cycle cost-effectiveness. Energy savings were based on a Project Conserve analysis of a 1500 square-foot wood-frame residence. Costs were collected from industry sources. Energy prices were based on DoE regional projections. Climate zones will be based on the ARI Research Corporation Building Energy Performance Standards recommendations. Resulting data will be differentiated by climate, heating fuel type, and the use or non-use of central air conditioning.

Performance of UF Foam Insulation

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Structures and Materials Division

Sponsor: Department of Energy

In this project, a field survey will be conducted to open the walls of homes that have been retrofitted with loose-fill cellulose, loose-fill mineral fiber, or urea-formaldehyde foam insulations. The insulations will be at least 2 years old and the homes will be located in various climatic areas including cold regions, and hot and humid locations. Observations will be made on performance parameters such as the condition of the paint on siding, corrosion of metal wall objects, moisture accumulation, odor, wood rot, fungus or mold growth, vermin, and workmanship during application. Settling of loose-fill materials and shrinkage of foam insulations will be measured. Insulation samples will be removed from the walls and measured in the laboratory to determine density, thermal conductivity, and moisture content.

Weatherization Demonstration

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Sponsor: Community Services Administration

The objectives of this project are to develop a field method for evaluating combinations of energy conserving options, to measure the energy and cost savings associated with these options, and to develop installation standards to assure consistent performance of the options when installed.

A sample of 300 frame, masonry and masonry veneer, one-and two-story houses have been selected in 16 cities across the United States. More than 200 of these houses are being weatherized with both architectural and mechanical energy-conserving options based on life-cycle cost principles. The effectiveness of the package of options selected for each site is evaluated by comparing actual installation costs with savings determined from pre-and post-retrofit utility bills. Individual houses are more intensively evaluated using newly developed diagnostic test procedures to determine the relative importance of infiltration, conduction, heating system efficiency, and water heater efficiency. This provides more detailed information on the energy conserving options, and leads to weatherization installation standards to assure that performance meets predicted values.

The results provide CSA with a quantified basis for their weatherization program. The results will also provide a field check on the accuracy of ASHRAE and other current energy calculation procedures for residences, leading to suggestions for improving calculations used in predicting energy performance in residences.

Economic Analysis of Weatherization Program

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Sponsor: Community Services Administration

To determine an economically optimum weatherization package, the cost and energy savings of the individual retrofit features must be known accurately. The packages installed in the demonstration houses were originally selected on the basis of predicted costs and savings.

Cost data on each retrofit feature are being collected for each house in every participating city. The basic cost components are labor, materials, prep-cost, and "other." For each city the average cost of the typical retrofit features installed are being calculated so that they can be compared with the value of the energy savings. The optimum weatherization package is being re-evaluated on the basis of these post-retrofit comparisons. For each house the net present value is being calculated for the entire weatherization package as well as for the four major types of options: (1) infiltration; (2) conduction; (3) mechanical; and (4) hot water.

Cost-Effectiveness of Infrared Heat-Loss Surveys

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Sponsor: Department of Energy

Although thermal surveys of buildings are considered to be highly efficient from a technical viewpoint, they are much more expensive than traditional inspection methods. The traditional methods, however, are less reliable. This project will correlate the energy savings, costs, and techniques of infrared scanning to calculate the most effective way of doing such surveys in urban residential areas. The surveys will be carried out by contractors in ten cities. The results will be submitted to the ASHRAE committee on standards for thermographic inspections.

Federal LCC Guide for Energy Conservation

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Sponsor: Department of Energy

NBS Building Science Series 113, *Life-Cycle Costing for Selecting Energy Conservation Projects for Public Buildings,* provides a step-by-step guide for conducting life-cycle cost evaluations of energy conservation projects for public buildings. It explains the use of life-cycle costing analysis to evaluate and rank the cost effectiveness of alternative energy conservation retrofit projects to existing public buildings, and to select the most cost-effective design for new buildings. Worksheets, illustrated with a realistic example, and a computer program are provided.

This guide is compatible with a life-cycle costing guide prepared for the Department of Energy for use in the Federal Energy Management Program by Federal Agencies. The purpose of this report is to provide a guide to state and local governments for use in their energy conservation programs.

The purpose of this project is to refine this guide and to add tables for estimating energy and non-energy life-cycle costs. This material was published in the Federal Register in February and will be the subject of Public Hearings in April and is expected to be issued as Final Rules in June 1979.

Economics of Residential HVAC Equipment Design

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Sponsor: Department of Energy

This project is in direct support of a larger CBT program, Building Energy Performance Criteria, which is intended to provide sample energy budgets for single-family dwelling prototypes. 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.

Under this project, modifications to HVAC equipment used in residences have been selected for analysis. Changes in the seasonal performance of the heating and

cooling equipment have been analyzed to determine the incremental effects of alternative designs. Cost data and energy price data were collected for use in the economic analysis. An algorithm for integrating the equipment design selection with the shell design was developed. This algorithm was computerized for the analysis of the equipment design selection. A final report on the results of this analysis will be prepared this year.

Economics of Masonry Wall Design

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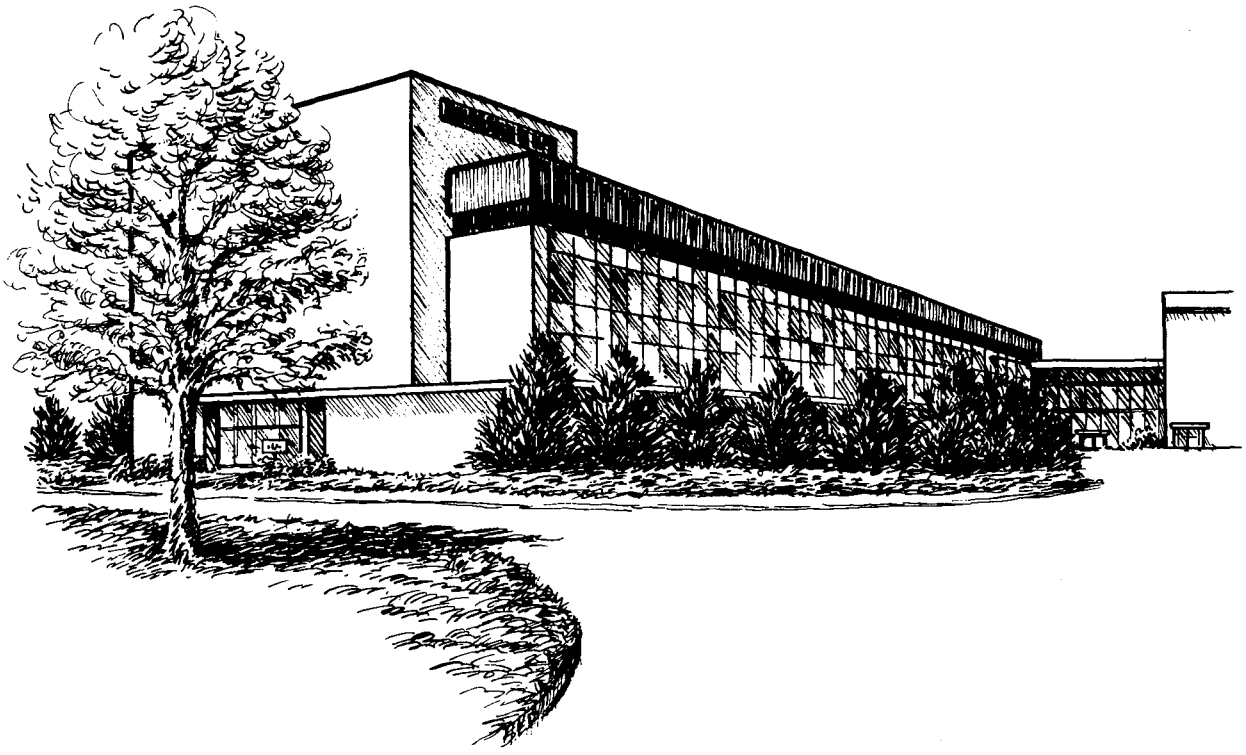
Sponsor: Department of Energy

Thermal insulation in exterior walls of buildings can significantly reduce heating and cooling requirements with net savings in life-cycle costs. While considerable data are available on the savings and costs attributable to insulation in wood-frame walls, these data are not directly applicable to masonry wall construction.

As part of this project, the typical masonry wall types and methods appropriate for insulating those walls have been identified. A model residence, compatible with the various wall construction methods to be examined, has been selected. The NBSLD load determination program has been used to calculate the effect of different insulation levels in walls constructed of concrete blocks in a variety of climates. Sensitivity analysis with respect to surface absorptivity and operational characteristics of the house has been performed. An economic analysis of the various insulation levels has been made to determine which level provides the greatest net benefits for given climate conditions, operational conditions, and energy costs. Additional computer analysis of brick veneer walls and heavy-weight concrete block walls, together with economic analysis, will be completed this year, leading to the publication of an NBS report.

Performance of Insulated Building Envelope



Thermal Conductivity Apparatus for Thick Insulation

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Sponsor: National Bureau of Standards

The objective of this project is to design and construct a 1-m diameter thermal conductivity apparatus capable of precisely measuring the insulating value of building insulation up to 0.4-m thick. The line-source apparatus will be put into service and calibrated to establish a reference base for industry and private testing laboratories. The performance of the apparatus will be described in publications and in technical committees of ASTM and ASHRAE. Subsequent research results on the study of combined heat transfer by conduction and radiation in thick layers of low-density insulation will also be published.

Auxiliaries for the Line-Source Apparatus

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Sponsor: National Bureau of Standards

The increased use of thermal insulation, because of the national effort to reduce building energy requirements, mandates the development of an accurate measurement capability to provide accurate thermal conductivity data, especially for thick, low-density specimens. This project will be used to procure electronic instruments, hydraulic equipment, and a conditioning chamber where thermal conductivity of thick specimens can be measured.

Thermal Insulation Standard Reference Material

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Sponsor: National Bureau of Standards

Thermal conductivity and resistance Standard Reference Materials (SRMs) for use in the calibration of thermal measurement systems in laboratories are needed. Although candidate materials are available from commercial sources under special order, data need to be analyzed to support their certification as SRMs. Under this project, a stock of high-density fibrous glass boards have been certified as SRM 1450. A new lot of material has been ordered to replenish the present stock. After selected pieces of material are measured, statistical analyses are then made, as are recommendations as to certification of the new lot as an SRM.

Many low-density fibrous glass materials have also been ordered. Measurements and analyses to support characterization as an SRM are to be made. However, work needs to be done to develop an equation representing the complex heat-transmission phenomena in low-density fibrous insulation. This analysis will be done as a future task.

Permanency of Fire Retardants in Insulation

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Sponsor: National Bureau of Standards

For fire retardants to be effective in insulations, they must remain as an integral part of the insulation. Any settling, sublimation, or dissolution of the fire retardant additive due to vibration, temperature, or moisture may reduce its effectiveness. Research is needed to determine the permanency of fire retardants in cellulosic insulations. A current study, *Effects of Moisture in Retrofit Insulations,* will continue to develop data to determine the effects of moisture on the permanency of fire

retardants in cellulosic insulations. In cooperation with the Center for Fire Research, flame spread and smoldering properties of cellulosic insulations will be determined both before and after exposure to water vapor. Fire retardants in cellulosic insulations will be determined for specific conditions of exposure to moisture.

Corrosion and Cellulose Insulation

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Structures and Materials Division

Sponsor: Consumer Product Safety Commission

Reports on home insulation have indicated that some chemical additives, e.g., aluminum or ammonium sulphate, when present in sufficiently large concentrations, can cause the corrosion of metal products in residences. The reports include cases of corrosion of metal support members and copper piping. It is possible that these flame retardants may also cause corrosion of electrical connectors at junction boxes and fixtures with a resultant loss of system ground, corrosion of gas piping with resultant gas leaks, and corrosion of metal vent piping with resultant leakage of carbon monoxide. Therefore, excessive corrosiveness associated with the use of chemical additives could present a safety hazard. The overall result of this project will be a new corrosion test for insulation.

Thermal Resistance of Roof Systems

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Sponsor: Department of Energy

Under this project, a literature survey on built-up roof systems will be performed to identify factors that affect their thermal performance. A field measurement technique and procedure, using infrared thermographic imaging and local heat-flow and temperature-difference measurements, will be developed for assessing the thermal resistance of built-up roofs. The measurement system will be obtained, assembled, and measurements will be made on laboratory samples. The system will be available next year to measure the thermal resistance of actual roofing systems.

Thermally Efficient Roofing Systems

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Sponsor: Department of Energy

There have been serious problems associated with roofing containing increased amounts of insulation (lower U-values). Small amounts of moisture in some insulations will significantly reduce thermal efficiency. Moisture in roof systems has led to premature membrane failures such as blistering, splitting, ridging, and wrinkling. Increased amounts of insulation necessary to obtain lower U-values in roofing systems have been asserted by the National Roofing Contractors Association to drastically shorten the life of built-up membranes.

Under this project, laboratory tests will be conducted to determine the effect of the amount and distribution of moisture on the thermal conductivity of roofing insulations and systems. The information derived

regarding the thermal performance of roofing systems containing various amounts of moisture is an important step in providing the necessary technical basis for guidelines and criteria increasing the thermal efficiency of the nation's low-slope roofing systems.

Large-Scale Test Apparatus

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Center for Building Technology
Headquarters

Sponsor: National Bureau of Standards

Under this project, a large-scale test apparatus capable of measuring air, moisture, and heat transfer characteristics of walls, roofs, floors, and joints between the roof and wall, and floor and wall will be designed and constructed. Our large environmental chamber and one other environmentally controlled laboratory, if needed, will be dedicated to the program. Under a technical contract with an A/E firm, a laboratory wall tester, one or two laboratory floor/ceiling testers, a mobile laboratory, a laboratory solar simulator (if needed), and a slab-on-grade apparatus will be designed and constructed for developing test procedures, performance criteria, and standards in this field.

Thermal Performance of Major Building Elements

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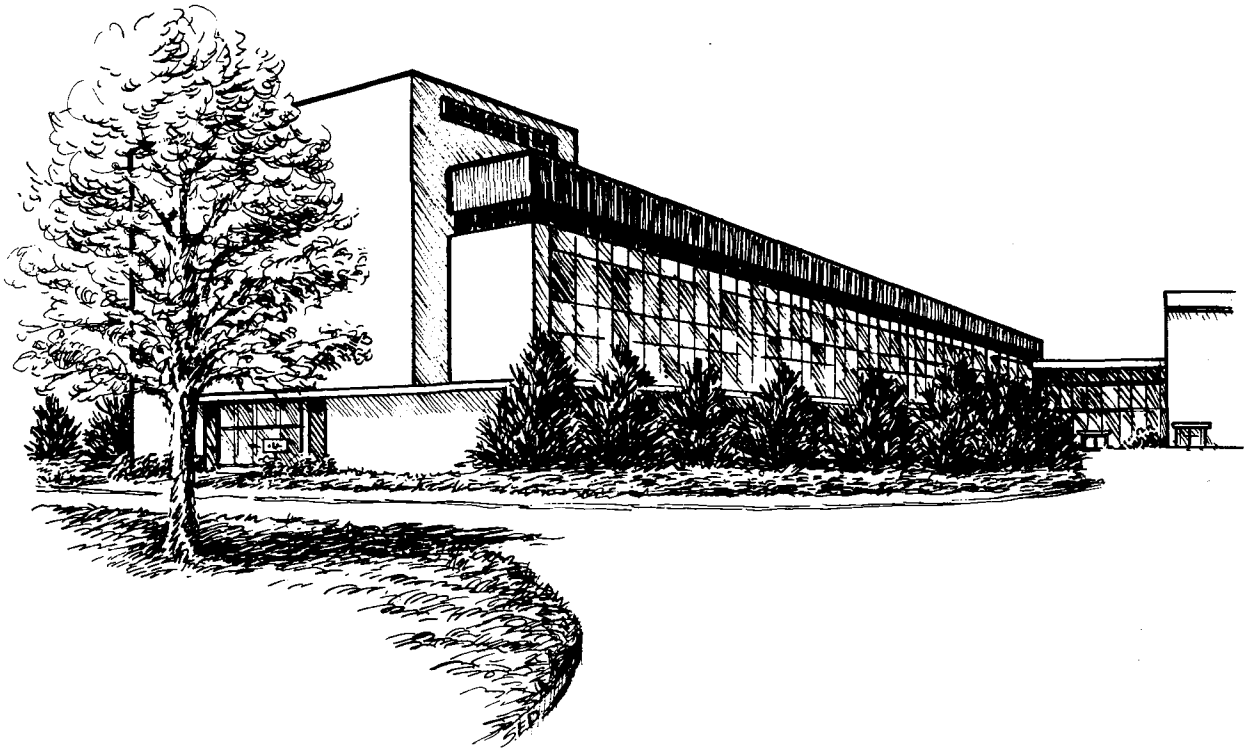
Center for Building Technology
Headquarters

Sponsor: Department of Energy

Under this project, new technical data and test equipment and procedures will be developed for design purposes and for standards on the building elements (walls, floors, and ceiling/roofs) to reduce energy requirements of buildings while retaining acceptable levels of functional effectiveness, durability, safety, and cost. The project will be carried out as a part of a comprehensive plan developed in cooperation with the Department of Energy, Oak Ridge National Laboratory, the Lawrence Berkeley Laboratory, and the building industry. 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.

Building Solar Systems Technology



Development of a Solar Regulatory System

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Building Economics and Regulatory Technology

Sponsor: Department of Energy

To make solar energy a viable and maturing energy source for the Nation, the regulatory system must not impede technical development. Under NBS leadership, a solar regulatory survey was conducted throughout the industry.

Using the NBS study as a base, this project is developing model solar building regulatory provisions in a consensus mode under the sponsorship of the Council of American Building Officials, using the ANSI-accredited organization approach. In addition, CBT, DoE, and HUD are collaborating in the overall planning for this program and, from time to time, are providing oversight assessments regarding the progress of the program.

International Standards for Solar Energy

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Building Thermal and Service Systems Division

Sponsor: Department of Energy

CBT has a major role in the preparation of performance criteria and test methods for the use of solar energy in the United States. DoE has requested that this expertise be used to contribute to the formulation and evaluation of international standards. This project will foster the development of such standards by participating in international critiques of U.S. and foreign interim standards and by taking part in round-robin thermal performance and durability tests of thermal collectors.

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 and field studies and will be submitted to the ASTM for consideration as consensus standards.

ASTM acceptance is expected by the end of this fiscal year. 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.

Performance 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 the exterior environment 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 draft performance standards for cover plate materials used in flat-plate solar collectors.

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

Standards for Rubber Hose and Connections

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Sponsor: Department of Energy

Rubber hose is an economical and efficient connector between the solar collectors and manifolds on the supply and return lines of solar energy systems. Rubber hose is sometimes also 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 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 that 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 submitted to ASTM for consideration as consensus standards.

Standards for Nonmetallic Containment Materials

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Sponsor: Department of Energy

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.

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 were identified. Tests were then assessed to determine if modifications were necessary to reflect solar conditions in use. Laboratory and field studies are being performed to obtain data needed to prepare testing standards. Draft standards will be submitted to ASTM as possible consensus standards.

Metal Containment Materials

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Structures and Materials Division

Sponsor: Department of Energy

There are no standard tests for selecting containment metals 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 E-44. The findings have resulted in an ASTM-recommended practice for metallic containment. This recommended practice describes a series of tests to evaluate the compatibility of metal-liquid pairs under a variety of environmental conditions.

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 establishing 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. Laboratory and outdoor field exposure tests will be performed on

solar collectors and their materials. The result 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.

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 drifiting 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 induced loads associated with movement of collector arrays and their structural supports must be considered. For certain collector systems the technical information required for safe and economical structural design is not available. The purpose of this project is to develop structural performance criteria and guidelines, especially for collector supports and fasteners. The results of the research will be used by designers and code writers.

Evaluation of Corrosion Test Methodology

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Sponsor: Department of Energy

Under this project, a laboratory test that simulates the in-service operation of a solar collector system is being developed. The intent of this effort is to provide a test methodology as a basis for selecting metal-fluid pairs to be used in solar collector systems, for accelerated testing, and for evaluating buffers and corrosion inhibitors.

Design of a test loop allows consideration of the effects of elevated temperature, temperature cycling, rate of fluid flow, and aeration or de-aeration on the rate of corrosion. The test loop is also designed to allow the use of either tubular samples or sections removed from actual collectors to be evaluated.

Dimensional Considerations in Solar Installations

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Building Economics and Regulatory Technology Division

Sponsor: Department of Energy

In active solar systems, using collectors, storage units and reticulation networks, the change to metric measurement is likely to affect most components and their dimensional relationships, including joints and tolerances. An awareness of the implications of metrication, dimensional coordination, and the dimensional options for solar systems should assist the U.S. community to make cost-effective decisions in the hardware context. It should also make it possible to avoid misfit problems. The identification of preferred sizes for system components will allow greater interchangeability, standardization, and direct performance comparison of dimensionally similar units. The major thrust of this project is to assess dimensional considerations and to illustrate compatible solutions.

Regulatory Impact Analysis of the Solar Demonstration Program

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Building Economics and Regulatory Technology Division

Sponsor: Department of Energy and Department of Housing and Urban Development

DoE and HUD are installing a significant number of solar devices around the nation in a demonstration program to collect data on the actual performance of solar devices in the field and to stimulate the commercialization of the solar industry. As an adjunct to this effort, a great deal of data is being gathered on the various technical and institutional aspects of this program. The thrust of this project is to gather and analyze the data collected on the building regulatory factors of this demonstration program and to identify barriers that will prevent the installation and use of solar systems. Information abstracted from the overall CBT solar data base is being compiled and analyzed to provide an insight into regulatory issues related to the application of solar energy. Organizations involved in the demonstration program that have not provided regulatory information to the CBT data base have also been contacted to capture any regulatory data they may have compiled. Significant problems and trends are being identified.

Solar Commercial Handbook

Rosalie T. Ruegg
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Building Economics and Regulatory Technology Division

Sponsor: Department of Energy

Building owners, builders, architects, engineers, lenders, manufacturers of solar energy equipment, government agencies 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 will be accomplished through the publication and distribution of a technical report containing the methodology and details of the thermal and economic analyses of well-defined solar heating and hot water systems in selected types of office buildings in different regions of the U.S. A simplified handbook for the building community that will promote interest in the use of solar energy and reduce the uncertainty concerning the economic feasibility of solar energy for selected types of commercial buildings will be prepared.

Solar Evaluation of the Norris Cotton Building

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Building Thermal and Service Systems Division

Sponsor: Department of Energy

A solar energy system has been integrated into the heating and cooling systems of a federal office building in Manchester, New Hampshire. This building was specifically constructed to demonstrate energy conservation features for commercial buildings. Under this project, tests of individual solar panels of the four types in this system will be made to compare collector performance with the requirements in the original contract specifications. Performance data will be gathered on a long- and short-term basis by an automated data system. The contribution of the solar system toward reducing fossil fuel requirements will be determined. Quarterly reports on the performance of the system as

measured at the building will be produced. A report on the performance of the solar panels tested in accordance with ASHRAE Standard 93-77 will also be written.

Thermal Test Methods for Solar Collectors and Storage Devices

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Building Thermal and Service Systems Division

Sponsor: Department of Energy

Standardized testing and rating procedures for solar collectors in a form similar to those published for fuel-burning equipment, air conditioners, and heat pumps are needed. Many different kinds of solar collectors are now being developed at various universities and research laboratories and there is an urgent need to be able to compare their performance on some common basis. In addition, commercial models of various collectors are now available and the procedures provide an equitable basis for competition among manufacturers and an essential basis for design and selection of equipment.

So far, under this project, standardized testing procedures for solar collectors have been proposed and adopted. Test facilities incorporating three test stands for conducting indoor and outdoor tests of solar collectors have been constructed at CBT. The procedures will be investigated, verified, and modified.

Passive Solar Data Requirements

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Building Thermal and Service Systems Division

Sponsor: Department of Energy

Although passive systems exist and are growing in number, quantitative thermal performance data are lacking, and a quantitative comparison with another passive or actively heated and cooled building is difficult. The expanding research and development efforts and the fact that passive and hybrid installations now exist in both the residential and commercial portions of the National Solar Heating and Cooling Demonstration Program require that consistent methods of evaluating their thermal performance be established. Under this project, a survey will be made of all the types of passive systems in an attempt to classify them. For each category, a list of pertinent performance factors will be established. Based on the established performance factors and a review of previously used experimental techniques for these systems, all necessary measurements will be identified along with the required accuracy. Following this, recommendations will be made for specific instrumentation as well as for data analysis techniques.

A small test building will be built at CBT and will provide flexibility in studying passive systems and evaluation procedures. The building will be used to investigate various levels of instrumentation and data acquisition for determining heat flow, natural convective air flow, comfort, and materials performance. The data from the building will be compared with the performance of passive systems in other climatic regions.

Solar Hot Water System Test Program

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Building Thermal and Service Systems Division

Sponsor: Department of Energy

Under this project, two simultaneous experiments are being conducted. In the first, six representative double tank, water-heating and air-heating collectors, with pumped and thermosyphon flow, are being subjected to controlled field tests for twelve months. In the second experiment, controlled laboratory tests are being run on selected components with simulated solar input to examine the effects of stratification and heat exchangers on system performance as well as to examine alternate methods of testing complete systems in the laboratory.

A letter report comparing experimental data with the performance predicted by the computer simulation codes for the six field-installed systems for July, August, and September 1978 has been written. A final report containing 12 months of experimental data and comparisons between the codes and actual data for the same period of time will be published. In addition, drafts of the recommended test procedure for testing solar domestic-hot-water systems will be prepared with substantiating data for consideration by ASHRAE.

Standards for Solar Collector Insulation

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Structures and Materials Division

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. This project is being performed to develop draft standards for evaluating the performance of insulation used in solar collectors. Environmental conditions within the solar collectors, and properties of the insulation material that contribute to the performance and durability of insulation have been identified and evaluated. The results of the study have led to the development of draft performance standards that are being submitted to the ASTM for consideration as consensus standards.

Monitoring Methods for Low-Cost Residential Solar Systems

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Building Thermal and Service Systems Division

Sponsor: Department of Housing and Urban Development

The successful large-scale use of solar energy for residential space or domestic hot water heating is predicated on proper operation of the system, without the use of sophisticated monitoring apparatus. Experience obtained by HUD in the Solar Demonstration Program and by others has indicated the performance of non-instrumented installations can vary significantly from one unit to another because of undetected operational problems. One method of minimizing the effect of these problems is to provide the operator with a set of systems capable of detecting and displaying improper operation. Under this project, three levels of instrumentation, ranging from meters to onsite minicomputers, will be installed in the CBT solar townhouse. This

instrumentation will be evaluated for ease of installation, operation, range, accuracy, cost, and appropriateness.

Application of Solar Technologies in Cities

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Environmental Design Research Division

Sponsor: Department of Energy

Heating buildings accounts for about one-sixth of the nation's energy consumption. Solar energy is acknowledged as a logical source for this heat and its use is increasingly common in rural and suburban areas. More widespread use of solar energy in urban settings has not occurred because of physical, social, political, and economic barriers. This project will analyze these barriers and recommend technical options for enlarging the use of solar energy in cities.

CBT is providing the technical research support to a DoE program to promote solar technology in cities. The research findings will provide physically sound design and evaluation procedures for use in selecting sites and designing cost-optimized systems for the sites. They will be used both for specific prototype sites targeted for the demonstration and for broader dissemination to professional design associations, governmental agencies, and trade groups and business associations to encourage opportunities where solar applications can be integrated into ongoing rehabilitation grants programs.

Economic Evaluation of Passive Solar Designs for Urban Environments

Rosalie T. Ruegg
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Building Economics and Regulatory Technology Division

Sponsor: Department of Energy

This project is aimed at increasing the application of solar designs in cities by developing evaluation methods, cataloging systems and materials, conceptualizing prototype solar applications, developing guidelines for their use, and estimating the energy benefits and life-cycle costs of the prototypes. The cost-effectiveness of solar designs is a critical factor to their widespread adoption. Developing a framework for performing economic evaluations of passive solar designs and applying this framework to the evaluation of the prototype are key areas of work to be performed this year.

Solar Energy Program for Housing Systems

Robert D. Dikkers
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Building Economics and Regulatory Technology Division

Sponsor: Department of Housing and Urban Development

This project will help to 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 first revision of the residential performance criteria document has been published as NBSIR 78-1562, *Interim Performance Criteria for Solar Heating and Cooling Systems in Residential Buildings—Second Edition,* and has been distributed to HUD, DoE, the building community and the public sector. Revisions are also being prepared for the HUD intermediate minimum property standards for solar heating and domestic hot water systems which was

issued in July 1977.

The evaluation process during the Residential Demonstration Program involves studies of actual predicted systems and component thermal performance, the evaluation of operational problems (equipment failures, installation inadequacies, accidents, etc.) and the examination of institutional constraints (e.g., code problems). Three letter reports have been prepared to date and sent to HUD on problem identification of the solar systems used in the Residential Demonstration Program.

Commercial Solar Energy Demonstration

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Building Economics and Regulatory Technology Division

Sponsor: Department of Energy

In view of the energy crisis and the increasing rise in the cost of fossil fuel, DoE began a cooperative program, with NBS in 1975 to determine the feasibility, use, and required performance characteristics of commercial solar energy systems in buildings using solar energy.

The interdisciplinary team, organized from CBT staff members, has continued to participate in the preparation of draft standards and performance criteria, and in the evaluation of demonstration systems performance. Experience gained from this evaluation has been fed back into the development of improved criteria which were published as an Addendum to *Interim Performance Criteria for Solar Heating and Cooling Systems in Commercial Buildings* (NBSIR 76-1187).

The tables presented in the standards plan (NBSIR 76-1134A) have been used by the ANSI Steering Committee on Solar Standards. Another report (NBSIR 78-1305A) containing provisional collector testing procedures is being used as the basis for a collector testing program being conducted for DoE. In addition, these testing procedures have been adopted in part for use in various collector certification programs (Florida, California, ARI) and are being considered for adoption as consensus standards by ASTM. The criteria developed for the evaluation of solar collector test labs (NBSIR 78-1535) have been used to identify laboratories qualified to participate in the DoE collector testing program.

Residential Solar Data Center

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Sponsor: Department of Housing and Urban Development

This project is concerned with the storage, processing, and transmittal of the technical and non-technical data collected by various HUD contractors from the Residential Solar Heating and Cooling Demonstration Projects. The outcome of this effort is an operational data center, transmitting computer reports on solar data to a variety of users and contractors for additional study, evaluation, and dissemination. The users on this project are HUD and their contractors: Real Estate Research Corporation, Boeing Aerospace Company, Dubin-Bloome and Associates, AIA Research Corporation, Franklin Research Center, and CBT. Technical reports

produced by these contractors will be disseminated to interested public groups, trade associations, and professional societies. Raw data reports are also analyzed by CBT for use in residential and commercial performance criteria.

Energy Analysis for Passive Solar Techniques

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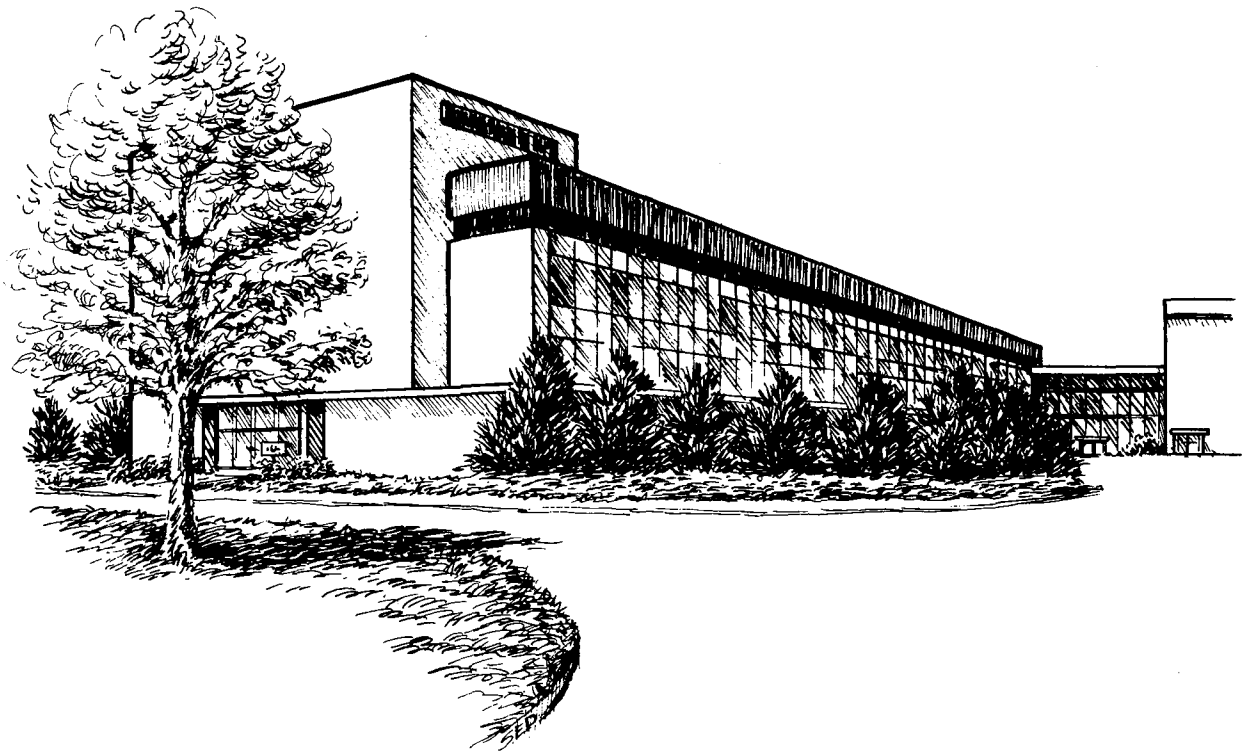
Sponsor: Department of Energy

This project will develop a method for calculating heat flow in buildings having passive solar characteristics (such as heavy weight construction) and to provide heat flow mathematical modeling elements for incorporation into existing energy analysis computer programs such as DoE-I and BLAST. The project will be broken down into four specific problem areas: response factors, conduction transfer functions and their application to thick, massive building constructions (concrete, masonry, or earth); multi-dimensional heat flow in various combinations of building constructions; radiation and convection conditions for heat balance equations at surface of building; and the optimal method for building heat transfer calculations employing multi-spaces (rooms or zones).

Earthquake Hazard Reduction



Earthquake Hazard Reduction

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Sponsor: National Bureau of Standards

Property losses from natural disasters such as floods, earthquakes, hurricanes, and tornadoes exceed $1 billion annually. Disaster assistance legislation (PL 93-288) and the Earthquake Hazards Reduction Act of 1977 (PL 95-124) emphasize the need for hazard mitigation activities. Under the Presidential Implementation Plan for the Earthquake Hazard Reduction Program, CBT has been assigned the responsibility for the development of seismic design and construction standards for state and local building codes. Additionally, CBT is to conduct research on performance criteria and supporting measurement technology for earthquake resistant construction. Work will include providing technical support to the Inter-agency Committee on Seismic Safety in Construction so that the Committee can develop uniform Federal standards by 1980.

Building Practices for Disaster Mitigation

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Sponsor: National Bureau of Standards

Disaster assistance legislation (PL 93-288) and the Earthquake Hazards Reduction Act of 1977 (PL 93-124) emphasize the need for hazard mitigation activities. This continuing research program is directed toward developing improved building practices for structures subjected to extreme environments through interactions with professional practitioners and post-disaster investigations. Such investigations have demonstrated that the application of improved building practices can significantly reduce losses due to natural hazards and have provided information on needed research.

Particular attention will be given to interactions with the newly formed Federal Emergency Management Agency and development of their role in coordinating the President's Earthquake Hazard Reduction Program and serving on the Interagency Committee on Seismic Safety and Construction. This will also include participation in the NSF Interagency Discussion Group on Disaster Mitigation, serving as CBT Liaison member to the USGS Advisory Committee, and representing CBT in an NSF project to develop a joint large-scale testing program with Japan. Products will include reports for improvement of building performance during disasters. One such report will be on the June 1978 Japanese earthquake.

Seismic Resistance of Reinforced Masonry

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During the recent development of tentative design provisions for buildings, information of strength-based design criteria for reinforced masonry was found to be inadequate. Development of improved criteria for the design of lightly reinforced masonry shear walls, which might be used in moderately seismic areas, is particularly needed.

An experimental program of research will be conducted on lightly reinforced masonry shear walls in order to determine behavior. Parameters will include

reinforcing quantity and distribution as well as gravity load.

These and other research data will then be used to develop recommendations for design.

Review of LNG Facilities

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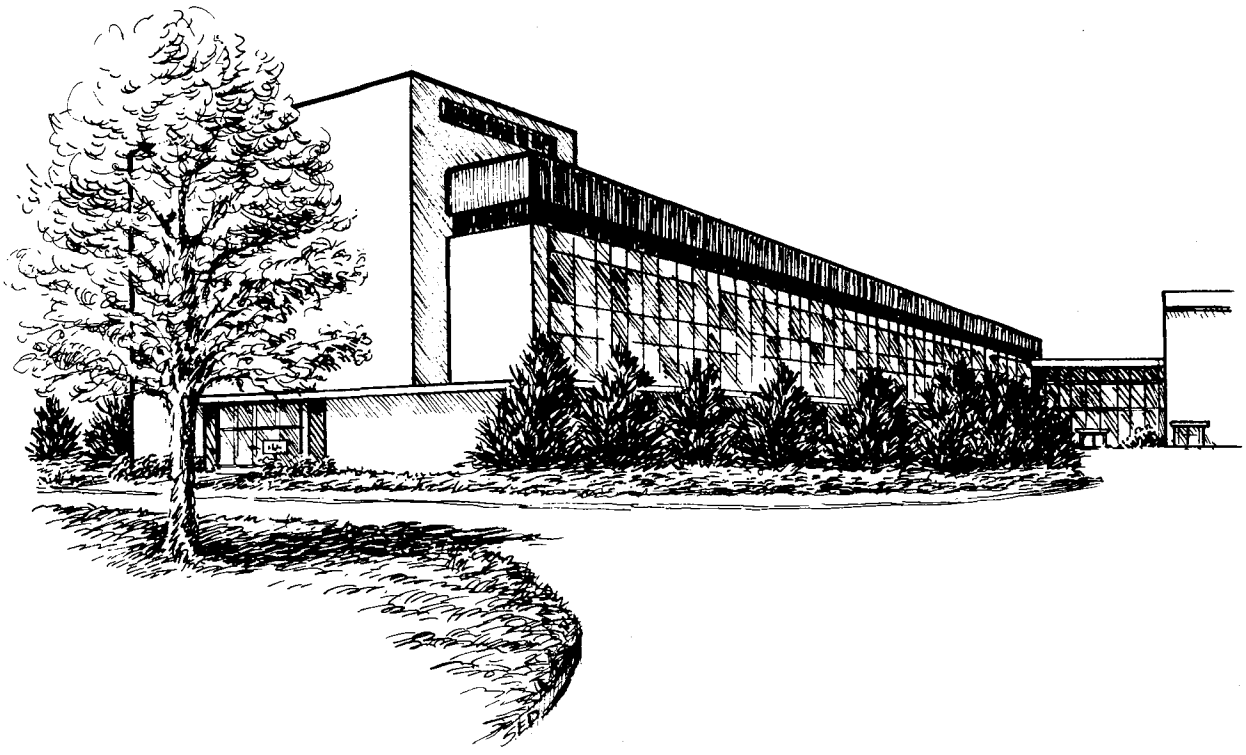
Sponsor: Federal Energy Regulatory Commission

CBT is reviewing the seismic design criteria associated with LNG storage facilities for a series of such facilities proposed for construction in a highly active seismic region. The project's technical approach will cover an assessment of the proposed seismic criteria by comparison with the seismic design requirements of the Nuclear Regulatory Commission for nuclear plants.

Structures and Foundations Performance



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.

A working group led by CBT has prepared initial drafts of standards on exploration, excavations, pier foundations, pile foundations, and shallow foundations. These draft standards are in various stages of revision. The American Society of Civil Engineers formed the Committee for Foundations and Excavation Standards, which is using the draft standards as a basis for a National Consensus Standard.

In Situ Geotechnical Measurements

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Sponsor: National Bureau of Standards

The first phase of this project deals with the Standard Penetration Test (SPT). A portable field instrument has been 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 uses 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. Field tests and calibration of a first generation system have been completed and a study is in progress 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. Since the SPT blow count is inversely proportional to delivered energy and delivered energy varies with equipment characteristics, the blow counts will vary for different types of drilling rigs used to perform the SPT within the same soil conditions. This study will measure energy delivered by as many types of U.S. drilling rigs as possible. The average and standard deviation of delivered kinetic energy for existing (and historical) U.S. practice will thus be determined. A decision will then be made whether to propose a new standard U.S. practice or to require energy delivery equivalent to that obtained in current Japanese and European practice. In the latter case it will be necessary to reinterpret and revise existing U.S. design guides that reflect the cumulative standard that then will be proposed for adoption by the

appropriate standards committee. The focus of the project will then shift to other areas. The area now being considered is measurement of soil parameters by electrical potential.

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 to mobile home occupants and damage to mobile home property. Approximately 5,000 units are heavily damaged or destroyed by wind storms each year. This project involves the collection of existing test data and information on theories and design procedures related to soil anchors. Available data from geotechnical field and laboratory investigations, including direct pull-out tests, standard penetration, cone penetration, and "Soil Test Probe" studies, will be assessed. Recommendations will address interim provisions for possible incorporation in the Federal Mobile Home Construction and Safety Standards as well as research needs for relating pull-out resistance to basic soil properties, installation torque or resistance, and simple penetration tests. Subsequently, the pull-out resistance of various commercially available ground anchors will be determined experimentally for several loading and soil conditions. The field test data will be correlated with the basic properties of the soils—as determined by standard field and laboratory techniques—to provide a basis for establishing an analytical model for predicting pull-out resistance. Performance criteria and a performance test method for structural links (i.e., tie-downs, connectors, etc.) and for anchor systems will be developed. The criteria and test methods will incorporate existing wind force information, along with anchor-resistance information obtained from the field tests.

Mobile Home Anchoring in Flood Plains

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Sponsor: Department of Housing and Urban Development

HUD's Flood Insurance Administration is faced with the problem of providing temporary housing to residents of flood-prone areas whose houses have been destroyed by major floods. This is accomplished by placing mobile homes in the immediate vicinity of the damaged residences. After major flooding, the soils on many sites in the flood plain remain saturated for a considerable time. This not only increases the probability of another major flood, but also leads to adverse foundation conditions. Mobile homes in all areas need to be anchored to the ground or otherwise secured to resist the sliding and overturning effects of high winds. In addition, mobile homes in flood plains need to be secured against the hydrostatic and hydrodynamic forces associated with floods. The objective is not only to prevent injury to residents and attenuate damage to the mobile home itself, but also to prevent the secondary effects associated with the flotation and dislocation of mobile homes, such as jamming of bridges and other obstructions and clogging

of waterways. At present, there are no data on the capacity of soil anchors in submerged soil.

Progressive Collapse

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Sponsor: National Bureau of Standards

With changing building technology, certain types of modern construction have become susceptible to the phenomenon known as progressive collapse. This is a sequential type of failure leading to structural failure in a major portion of a building. In spite of the potential for such failure, current codes and standards do not include design requirements against progressive collapse. Under this project, CBT will participate with the Progressive Collapse Subcommittee in the preparation of a criterion for inclusion in the 1980 revision of ANSI A58.1 (Minimum Design Loads). Using results of CBT research on post-tensioned flat-slab construction, reports will be prepared examining the progressive collapse resistance of that type of construction.

Tornado Missile Probability Assessment

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Sponsor: Nuclear Regulatory Commission

To ensure the safety of nuclear power plants, the designer must consider the possibility that the structure will be hit by tornado-borne missiles. Current specifications of tornado-borne missile speeds are based on a set of simplifying assumptions regarding the tornado wind flow and the aerodynamic behavior of the missile, and on a set of conditions chosen to yield generally conservative results.

It appears that the probability that a structure will be hit by a missile with speeds previously specified is considerably less than the probability of occurrence of the "design basis tornado." If this were indeed the case, then the missile speeds specified for design purposes could be reduced so that their values would be consistent, from the point of view of risk, with the "design basis tornado."

The proposed research will estimate missile impact velocities corresponding to various probabilities of occurrence of the impact. Probability levels to be considered tentatively include 10^{-5}, 10^{-6}, and 10^{-7} occurrences in any one year.

Available software will be used to generate missile velocity matrices providing information on maximum missile velocity within a volume for a sufficiently large set of initial conditions. Probabilistic information on missile impact will then be generated through multiplication of these matrices by initial-condition matrices obtained via random simulation.

Development of Revisions to American National Standards Institute A58

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Sponsor: National Science Foundation

ANSI mandates that its standards be reaffirmed or revised periodically to assure that they reflect the latest in engineering knowledge. The state of knowledge regarding loads on buildings has evolved and improved considerably since the current standard was issued in 1973, making its revision necessary. This work will satisfy the clear need on the part of code authorities and design professionals for a reference standard for design loads which incorporates the latest information on building technology and loads research.

Probability Distributions of Extreme Winds

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Sponsor: National Science Foundation

The NBS serves as the Secretariat for a consensus standard (ANSI A58.1—Building Code Requirements for Minimum Design Loads in Buildings and Other Structures) that contains provisions for the design of buildings to resist extreme winds. Current provisions are based on annual extreme speeds obtained prior to 1968 and do not reflect recent advances in extreme values analysis. The project will make possible the development of improved probability distributions and the eventual updating of wind load requirements contained in the model building codes. The project will be coordinated with another federal agency, the National Climatic Center, which will supply the basic wind speed data.

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 designs based entirely on the minimum load requirements specified in codes and standards. In recognition of this, the next edition of American National Standards Institute 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 test 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. 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.

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. Differences in philosophy (e.g., ultimate strength to consider uncertainties) cause a lack of consistency in the reliability levels of 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. However, while general methodologies 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. In the U.S., ANSI A58 has appointed a committee to investigate the feasibility of developing probability-based criteria for limit states design. This research 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 of 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.

Snow Loads on Nuclear Power Plant Structures

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Sponsor: Nuclear Regulatory Commission

Current design standards specify snow loads on roofs by multiplying the ground snow load by a snow load coefficient Cs. In ANSI Standard A58.1-1972, Cs depends on roof exposure and geometry. Except in valleys of sloped roofs and locations of elevation change, the load is assumed to be uniformly distributed. However, snow seldom accumulates evenly because of drifting and sliding and the loads may not actually be uniform, even on flat roofs. Thermal effects are not included in Cs, despite the evidence that the roof load may be significantly higher for unheated buildings or where the roof is heavily insulated. Finally, the coefficients in A58.1-1972 are based on Canadian studies of ordinary structures: the extent to which these data can be used to represent the different roof geometries in nuclear power plant structures is not clear.

Under this project, technical assistance to NRC to identify roof snow loads and develop loading criteria will proceed in two phases: (1) snow loads on power plant structures will be measured and correlated to ground

snow loads for several facilities in the NE quadrant of the U.S., and (2) data gathered in phase 1 will be integrated with existing data from similar studies for the purpose of recommending tentative snow load coefficients for design. A report will be prepared for the NRC giving the survey results and recommending snow load coefficients.

Modeling of the Cement/Concrete System

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Sponsor: Department of Energy

About one percent of the nation's energy goes into the manufacturer of the cement used in concrete. Possibilities for more efficient use of energy by the cement and concrete industries largely lie in improvements in cement manufacture and in the effective use of concrete. The conversion of raw materials into concrete involves many processes. Although each process can have a significant impact upon the energy used in another process, relationships describing interprocess effects have not been developed. One purpose of the present project is to recommend how a macro-model showing energy and performance relationships in the manufacture and use of cement and concrete might be developed.

The limitations of available models will be assessed. Their suitability for incorporation into a macro-model giving energy use in relation to the composition, manufacture, and performance of cement and concrete will be evaluated. A methodology for establishing a data base that can be coupled to the modeling effort will be developed. Specific cases where the modeling approach has been used will be analyzed to determine their effectiveness.

Thermal Loads on Concrete Slabs

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Sponsor: Federal Highway Administration

Thermally induced stresses or strains may significantly affect the performance of structures. Heat has been known to open joints and cause concrete to crack. In this project, a computer program will be developed to predict the magnitude of stresses and strains generated by heating concrete bridge slabs. 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 a 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 in order to achieve internally sealed concrete and by comparing the computer predictions with cracking actually observed.

Concrete Construction Technology

Existing standards for concrete construction are nonuniform and ambiguous and are often the underlying cause of needless increases in construction costs. This is

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Sponsor: National Bureau of Standards

due primarily to a lack of research data and information on concrete construction technology. Traditionally, design and erection of formwork and other construction-related work have been 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.

The near-term objective of this project is to develop an analytical model for predicting the capacity of single-post shores representing typical field conditions. The model will take into account out-of-plain, out-of-plumb, and various load-eccentricity end-condition relationships. A sensitivity study for each of these parameters will be investigated. The results will help identify variables to be considered for an experimental program to verify the model. Using the results of the parameter studies, laboratory tests will be planned and carried out to verify the model. 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.

Fire Resistant Structural Design

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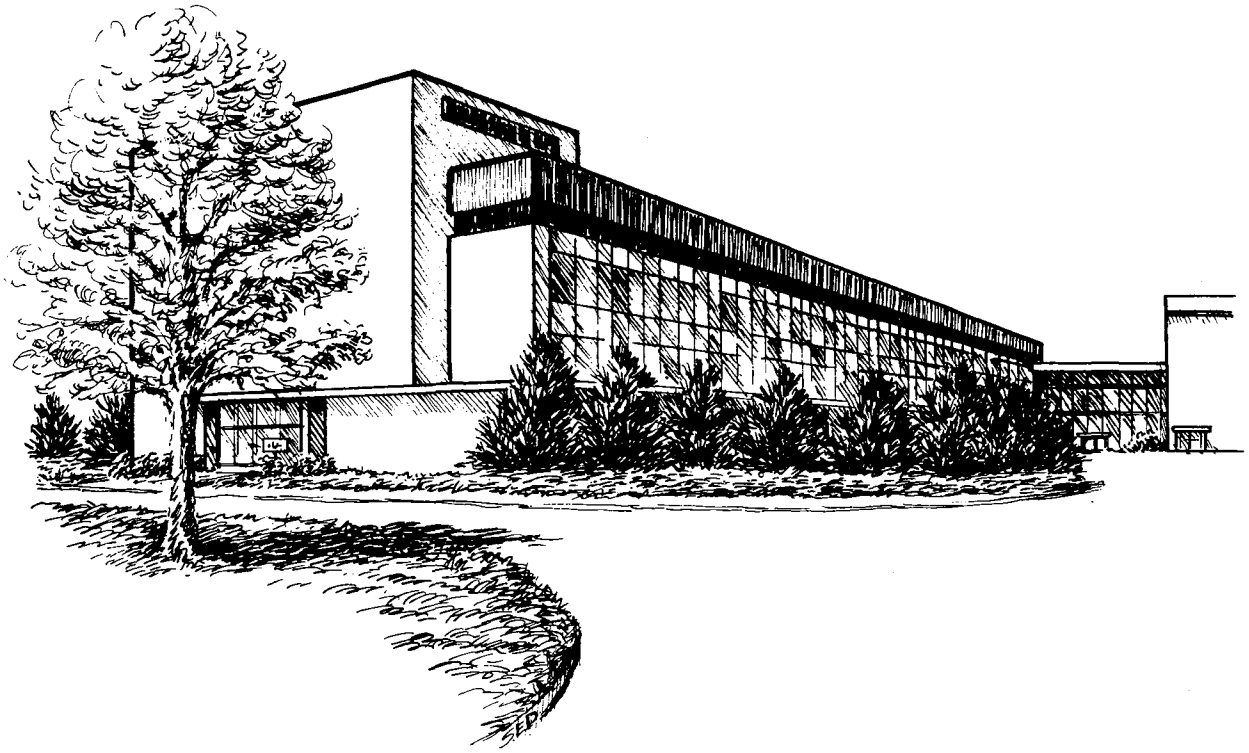
Sponsor: National Bureau of Standards

Fire resistance of structural components is currently measured in terms of endurance time or temperature rise in certain members or on unexposed surfaces by a standard ASTM E119 fire test of the component. In addition to being costly, these tests do not provide a basis for extrapolating to situations not covered by the limited test data. Moreover, while the ASTM test is useful as a standard comparison tool, it only provides an indication of how a component may perform in one particular kind of fire. The use of one fire exposure curve fails to account for variations caused by the amount of combustible materials, their composition, and compartment ventilation.

Under this project, CBT will develop computerized analytical procedures that predict the behavior and fire endurance for reinforced concrete members and frames subjected not only to the standard ASTM fire exposure but also the exposures which are more representative of fires that actually occur in buildings. The effect of continuity and constraints imposed by unexposed members on the fire endurance of reinforced concrete frames will be studied to determine which parameters are important in designing for a fire-resistant limit state and to make tentative recommendations for improvements in fire resistant design.

Building Safety And Security



Study of Construction Scaffolding Systems

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Sponsor: National Institutes of Occupational Safety and Health

Accidents on scaffolds and other elevated surfaces result in a major portion of the construction injury losses. Many of these accidents occur on elevated surfaces involving scaffolding. Under this project, survey and follow-up field investigations will identify critical scaffolding systems and their characteristics that are highly related to accidents. These critical systems will be studied closely. Emphasis will be on establishing a profile of typical scaffolding usage characteristics. The range of loads acting on scaffolding will be established by determining typical trends in loading from materials, equipment, workers, etc. Then, analytical techniques will be developed to describe scaffolding behavior, including failure modes. Safety criteria will be developed, which in turn will become the basis for future safety standards.

Measurement of Forces in Trench Bracing

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Sponsor: National Institutes of Occupational Safety and Health

Many deaths and injuries result from the cave-in of trenches and excavations (well over 100 fatal injuries and many more nonfatal accidents annually). Lack of knowledge of transient forces on trench bracings hamper the engineering profession and hinder the development of effective standards. Data on forces on shallow trench bracing are urgently needed so that analytical methods to calculate forces can be developed. Under this project, hydraulic shores installed as struts in trenches will be used to measure the pressure on trench walls. The results will be published as an NBS report and used to update the OSHA standard on excavation safety.

Analysis of the Willow Island Cooling Tower Failure

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Sponsor: Occupational Health and Safety Administration

CBT engineers are investigating the cause of the natural-draft cooling tower failure during construction at Willow Island, West Virginia. Fifty-one workers died as a result of the failure. Construction of the concrete tower, which is a thin shell of hyperboloid shape, employed unique techniques and procedures. CBT carried out field, laboratory, and analytical investigations that were used to support OSHA's failure investigation of the tower and will identify possible areas of improvement in the present construction procedure that could ensure safety in the future construction of such towers.

Effectiveness of Safety Symbols in the Workplace

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Sponsor: National Institutes of Occupational Safety and Health

Safety symbols that are now proposed for use have never been evaluated systematically for their understandability to workers in the built environment. The lack of evaluation presents a great potential for serious error, misinformation, and possible danger. Yet because symbols can provide a means of rapid and effective communication that is "language free," they offer the potential of being an effective means of conveying urgent safety information; particularly for those who do not read English well. As a result, this project will help develop a comprehensive testing and evaluation program to serve as the basis for criteria for effective symbol use in and around the workplace.

Symbols Criteria and Standardization

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Sponsor: National Bureau of Standards

Symbols in widespread use have neither been evaluated systematically for effectiveness nor designed in accordance with specified criteria. This presents a great potential for error. Symbols are now being used that may not be readily comprehensible or that may have confusing or contradictory meanings. The problem is particularly acute for owners and operators of multi-building complexes—hospitals, government centers—used by large numbers of new visitors. As a result, designers, the graphic arts firms, and building safety groups have identified an urgent need for a comprehensive testing and evaluation program to serve as the basis for criteria for effective symbol use in and around buildings.

In this project, the literature on the use and evaluation of symbols will be reviewed and a research plan developed for testing the effectiveness of symbols such as the fire safety and worker safety symbols now proposed for voluntary use by ISO, NFPA, and similar groups. Sets of symbols will then be selected and evaluated to determine the usefulness of different research methods. Researchers will share early results and exchange views with the NFPA Committee on Fire Safety Symbols, and with ISO. In addition, CBT will chair the ANSI Committee Z535 Subcommittee on 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 or the action to be taken by the viewer. Requirements addressing sign colors and legends are proliferating. 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 causes both confusion and cynicism.

This project will address these problems through literature searches and 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 set of universal conventions for visual displays.

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 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. This year CBT will publish its survey of residences victimized by break-ins; a final report will detail recommendations to HUD.

Building Security Technology: Symposium

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Sponsor: National Bureau of Standards

This project covered the management of a national symposium on security issues that attracted a wide range of building managers, designers, and owners. Its outcome was a significant and comprehensive literature base from which future security planning can benefit and to which future symposia can add. Members of the symposium also included representatives of hardware manufacturers, security planning consultants, and federal government. The ASTM Executive Committee gave its full support and assistance. This symposium was held in April 1979 and the final ASTM/NBS publication of its report will be issued this fall.

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. 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.

At present, the mobile home test facility has been completed and human engineering tests with volunteer subjects will begin this year. HUD will use the research to make specific modifications to the Mobile Home Construction and Safety Standards.

Mobile Home Egress: Economic Analysis

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Sponsor: Department of Housing and Urban Development

This project covers the economic analysis component of the egress study. Work now underway has identified the costs and benefits associated with the egress requirements of the current HUD Mobile Home Construction and Safety Standard. Life-cycle, benefit-cost analysis has been performed for egress provision changes being considered by the CBT research team.

Building Access/Egress Research Planning

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Sponsor: National Bureau of Standards

Frequently, building codes and standards are viewed by designers as constraints to the building design process. As a result, minimum standards are often used as design maxima. Moreover, life-safety features are often viewed as "add-ons" rather than as elements of a logical system integrated with the overall building design. To a large degree, the structure of building code documents foster such conditions. In particular, no mechanisms exist that encourage designers to analyze the safety implications of alternative designs while these are still at the conceptual level. The purpose of this project, therefore, is to aid the completion of BFIRES, a computer simulation tool that enables designers to evaluate alternative building designs on the basis of emergency egress criteria.

Risk Assessment

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Sponsor: National Bureau of Standards

The federal government is concerned with the safety of its citizens in buildings, and therefore needs an explicit framework for specifying the levels of publically acceptable risk for different building types and for building-related activities. Especially the levels of risk associated with the use of building components need to be critically assessed. The risk of using a stair, one of the most hazardous consumer products, compared to an elevator or an escalator must be evaluated in a systematic fashion.

In this project, the risk literature will be critically evaluated to determine the current levels of risk now tacitly assumed by building users, the levels of publicly acceptable risk, and the possibilities for trade-offs among different risk levels. In addition, methods now used by the insurance industry and the regulatory community for determining and evaluating risks to users will be examined. Methods for quantifying loss and gain, the

potential severity of a particular type of injury, frequency of occurrence, the extent of exposure, and the degree of choice as to exposure will be included. The characteristics of different exposed populations and their expectations with regard to risk and its regulation will also be considered.

Walkway Slip-Resistance Standard

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Environmental Design Research Division

Sponsor: National Bureau of Standards

Slips and falls, often associated with slippery surfaces, are the nation's second largest cause of accidental death. The lack of a broadly applicable quantitative requirement for slip-resistance in existing codes and in voluntary standards has been a factor in the selection of slippery shoe materials, walkway materials, and maintenance procedures. For instance, many building codes require "slip-resistant" walkways, but none specifies how to measure the characteristic. This project will focus on developing a model performance requirement for the measurement of walkway surfaces. This year's activity will focus on the development of standard reference surfaces (to calibrate the various test devices available) and on the development of a data base of measurements of different floor materials in buildings of varying ages and subject to various maintenance regimes. Reports will be prepared summarizing the data collected on standard reference surfaces for the calibration of slip-resistance measuring devices.

Simulation of Human Behavior in Fires

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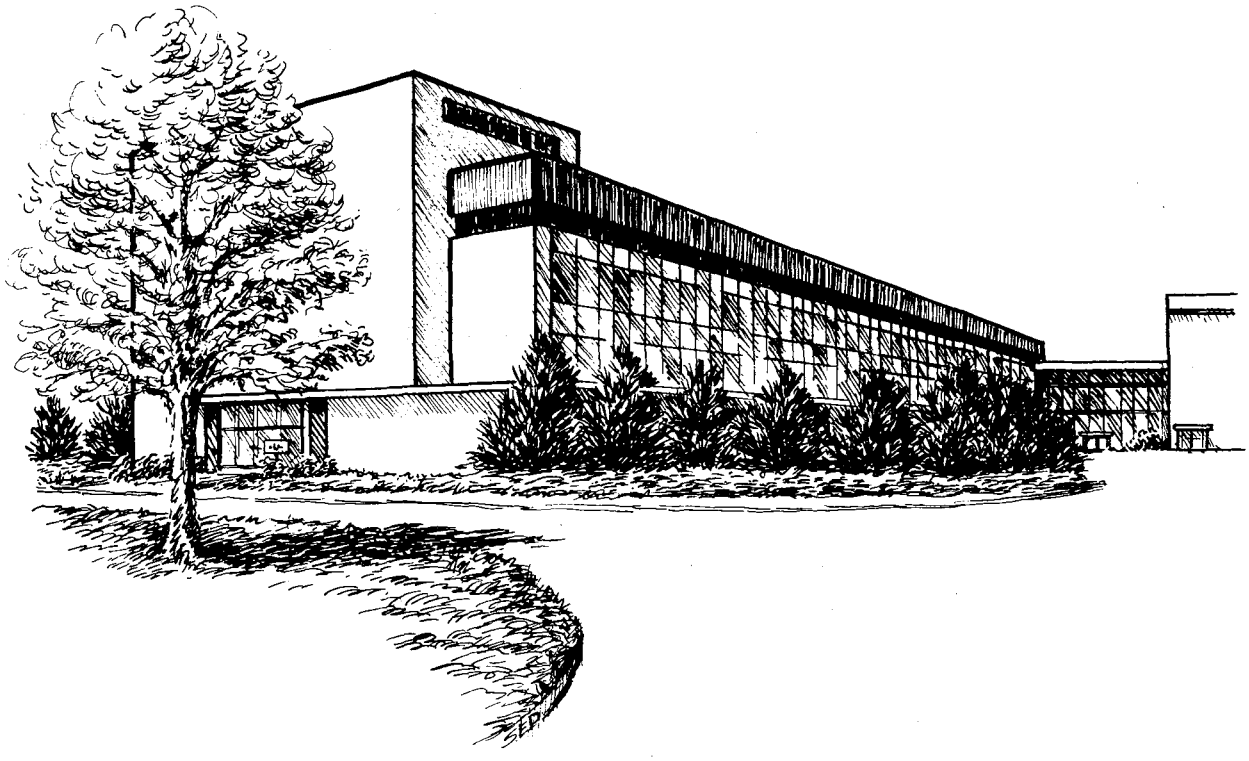
Environmental Design Research Divison

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

Last year, a computer program that simulates human behavior in building fires was prepared. The long-range objective of this simulation was to provide a tool with which building designers and code administrators could better assess the life safety potential of both planned and existing structures. This year, the project will continue with two major improvements to the BFIRES program. The first will enable BFIRES to simulate human behavior in spaces infiltrated by migrating smoke and flame; the second will enable BFIRES to simulate rescue activities. These enhancements will make the computer program more useful to the building design and regulatory communities, since they will enable more authentic simulation results under a wider range of conditions.

Building Rehabilitation Technology



Rehabilitation Technology

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Building Economics and Regulatory Technology Division

Sponsor: National Bureau of Standards

Activities in this project are in three specific areas: development of a technical evaluation manual for strength and stability; research to establish the technical basis of building regulations; and formulation of a rehabilitation research agenda. The technical manual will include test methods, methods of analysis to predict the performance of existing buildings, field inspection and evaluation methods, and data on outmoded systems. As for the technical basis for regulations, research will be carried out in selected areas to establish the justification for existing requirements affecting the reuse of buildings. The research agenda will include identification of and priority-setting among technological needs.

Preservation of St. Louis Courthouse

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Structures and Materials Divison

Sponsor: National Park Service

The old St. Louis Courthouse is one of the most 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 was a field inspection of the courthouse for the purpose of identifying material problems. Samples of brick, mortar, and paint were selected and analyzed. Based on the field inspection and laboratory work, recommendations were developed to assist the NPS in the preservation of the Courthouse. This year the project will help the NPS put these recommendations into use and will help generalize the suggestions for application to other historic buildings.

Structural Preservation of National Historic Monuments

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Structures and Materials Division

Sponsor: National Park Service

The National Park Service has requested that CBT provide assistance in identifying major structural problems that may exist in several historic monuments and advise NPS on the feasibility of various methods of structural repair that are compatible with NPS restoration guidelines. Investigations will be conducted to determine adequacy of the buildings to resist wind and seismic loads. Analytical studies based on existing data and additional data collected by NPS will result in recommendations for repairs.

Assessment of Building Rehabilitation Regulations and Processes

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Building Economics and Regulatory Technology Division

Sponsor: National Bureau of Standards

Under this project, a 1978 study of the regulatory processes in the 30 largest cities in the United States and a separate study of model building code organizations and selected State agencies will be used to develop a model enforcement process for existing buildings. Such a system would typically include: model forms for design submittals, regulatory review, and compliance inspections in the field; preconstruction meetings of owner, designer and building official; interaction between affected governmental agencies; appeal mechanisms; and availablility of technical resources. The model process will be demonstrated on a pilot basis in cooperation with a mix of local governmental jurisdictions that face

different types of rehabilitation activity. The outcome of this project will be a report outlining the model regulatory process for existing buildings and its rationale, which would be available for voluntary use by state and local jurisdictions.

Cost Estimates and Cost Variability in Rehabilitation

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Sponsor: National Bureau of Standards

Between 1972 and 1976 the median costs of new single-family housing increased at an annual rate of 12-1/2 percent. Such rapidly rising prices have forced many prospective homeowners to look elsewhere to satisfy their housing demands. This trend is likely to continue over the next ten years. Current forecasts indicate that between 22 and 30 million additional housing units will be needed by 1988. A significant increase in the number of housing units being rehabilitated is therefore likely. Since costs play a vital role in all investment decisions, any significant change in current housing investment trends calls for a reduction in the uncertainty associated with the extreme cost variability of residential rehabilitation.

Under this project, CBT analysts will review published material in the fields of investment theory, real estate appraisal, and cost estimation. Specific articles and case studies dealing with rehabilitation costs will be examined. Economists will then contact the publishers of the cost-estimation guides and professional cost engineers to determine the appropriateness of their assumptions when applied to residential rehabilitation. Based on these discussions and economic theory, building components in which cost variability is expected to be high will be identified. The type and nature of empirical data needed to reduce this cost variability will then be identified. Statistical and econometric techniques will be identified that will enable the expected range of cost variation to be predicted. Emphasis will be placed on those procedures which deal explicitly with risk.

HUD Studies

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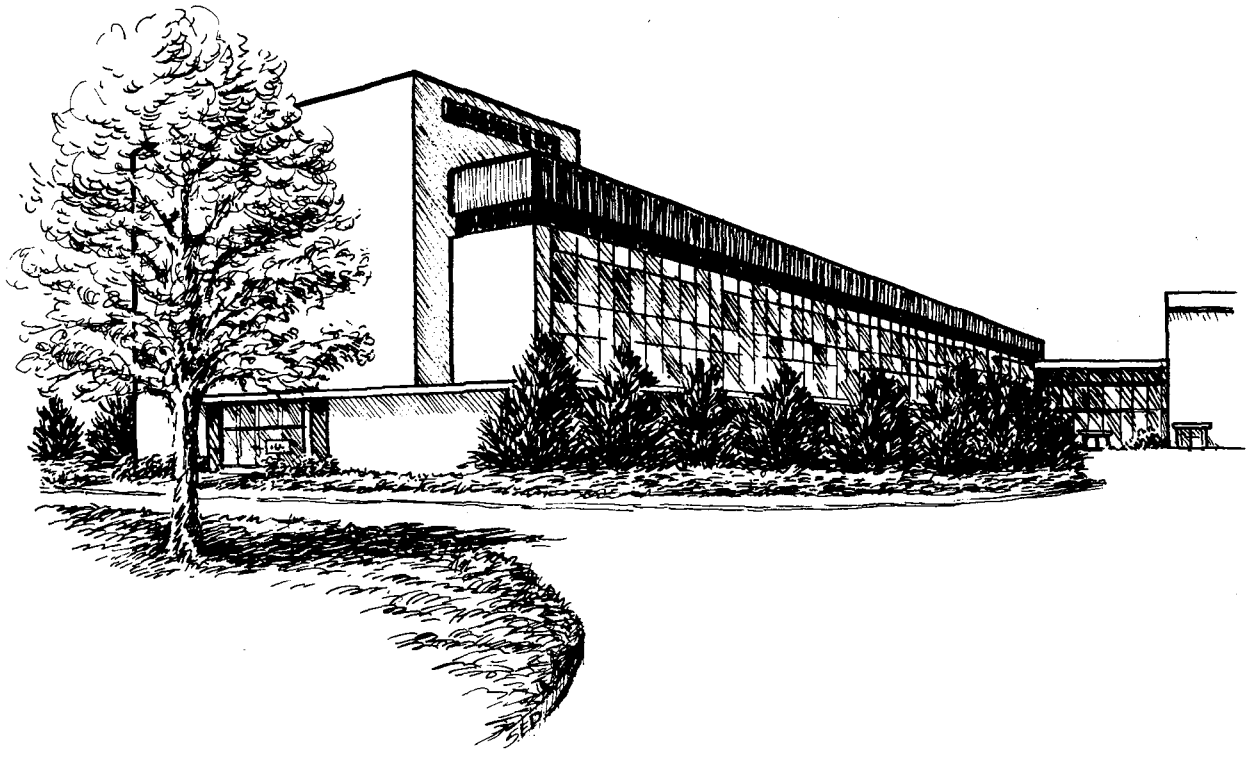
Building Economics and Regulatory Technology Division

Sponsor: Department of Housing and Urban Development

CBT will perform tasks for a wide variety of HUD research needs throughout fiscal year 1979. Each task will 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 air infiltration and thermographic measurements, site surveys to uncover pesticide leakage from treated structures, cost studies of insulation and storm windows, mobile-home heat loss, and sand-bag tests of single-layer floor systems; 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.

Building And Community Acoustics



Highway Noise Criteria

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Environmental Design Research Division

Sponsor: Federal Highway Administration

Noise from highways and urban traffic has been shown to be a serious source of annoyance to the public. Many government agencies, including the Federal Highway Administration, are trying to solve the problem. The FHWA is responsible for highway design noise standards for federal-aid highway projects. FHWA seeks to reevaluate its interim noise standards and procedures, incorporating considerations of human response to time-varying rather than steady-state noise. CBT has been contracted to provide FHWA with a data base on the human response to time-varying traffic noise necessary for this reevaluation.

CBT has analyzed the time histories and spectra of traffic noise from different traffic situations and has data on how traffic sounds are received in a building. Laboratory investigations are planned on the human response to the time-varying noises. From analysis of these experiments and in conjunction with the analysis done on the physical data base, it will be possible to evaluate existing rating schemes and, if necessary, develop an improved rating procedure. A questionnaire and measurement plan will be developed to assess occupant reactions to highway noise based on the key parameters.

Building and Community Acoustics

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Environmental Design Research Division

Sponsor: National Bureau of Standards

Accoustical treatment and noise management, if not made at the early stages of basic design, add significantly to the cost of new developments. Corrective measures are extremely costly. These measures are taken because of the effects of inferior acoustic performance on occupant satisfaction and worker productivity. These costs can be significantly lowered and even offset by savings if decisions about zoning, airport extensions, highway construction, and building design are made with regard to acoustical considerations. For example, the FAA estimates that soundproofing schools and health facilities in existing buildings in areas impacted by aircraft noise would cost the nation over $200 million but would result in energy savings of over $1.7 million and savings in teacher time of over $3 million annually. Real estate marketers are finding that the acoustic environment and noise management are important sales incentives and the design profession is under public pressure to bring about improvements in the acoustical environment through building and site planning. Work in this project will concentrate on three specific areas: human response, building acoustics, and sound propagation in urban areas. For each of these areas, emphasis will be on developing criteria, characterization methods, and predictive models with the aim of improving *in situ* performance and usefulness.

Transmission Line Audible Noise Measurement

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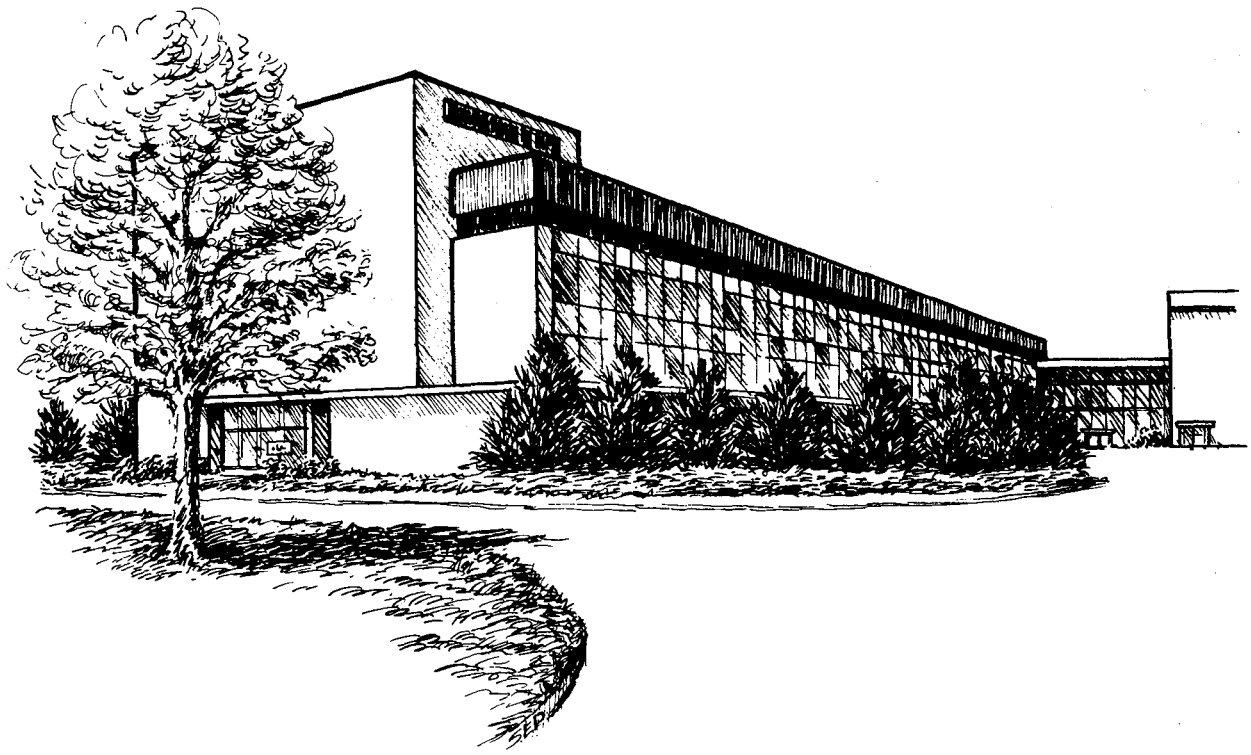
Environmental Design Research Division

Sponsor: Department of Energy

The most economical means for long-distance transport of electric energy is the overhead, high-voltage electric transmission line. Increases in transmission efficiency are achieved by increases in operating voltages. However, one of the major factors limiting the development of new ultra-high-voltage technologies is the audible (corona) noise produced by these lines under certain conditions. To manage this noise and to avoid costly retrofit measures, the project will obtain psychoacoustic data for land-use planning in the vicinity of power lines, and for construction planning for nearby building sites.

Corona noise samples for different weather conditions and from different transmission lines will be recorded with a remote tape recording system. In the laboratory these recordings will be processed along with recordings of other environmental sounds into stimulus tapes. These tapes will then be evaluated by listeners under realistic conditions approximating natural built environments. The effect of the building shell on the listener's response to corona noise will also be determined. On the basis of people's responses, criteria will be developed for characterizing the acoustic environment near transmission lines in terms that are relevant to human response, so that decisions about land use planning, building design, and construction may be based on users' needs.

Building Materials and Composites Performance



Modeling of Concrete Performance

James R. Clifton
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Structures and Materials Division

Sponsor: National Bureau of Standards

Portland cement concrete is the most widely used building material in the U.S. About 700 million tons are used annually. However, the selection of materials for use in concrete is largely empirical. Conservation of energy and materials is prompting 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. This year the project will publish two reports: one will review mathematical models for the hardening of cement; and the other will cover a mathematical model for hydration of tricalcium silicate.

Corrosion of Steel in Prestressed Concrete

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Structures and Materials Division

Sponsor: State Department

This is a cooperative project between CBT and the Laboratorio Central de Ensayo de Materials des Construccion (Madrid) on the factors affecting the corrosion of steel in prestressed concrete structures. Because the use of prestressed concrete is growing rapidly, it is important that the corrosion of prestressing steels should be well understood and methods for detecting the corrosion developed. The major causes of corrosion failure of steels in prestressed concrete will be identified, both in Spain and the U.S. The Spanish laboratory will investigate the microstructural features of prestressing steels that affect their susceptibility to corrosion. In addition, in collaboration with CBT, the effects of the physicochemical properties of concrete on prestressed steel will be determined. CBT will identify or develop nondestructive test methods to detect and to quantify the corrosion of steel in prestressed concrete.

Corrosion-Preventive Coatings

Paul G. Campbell
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Structures and Materials Division

Sponsor: U.S. Air Force

Inadequate performance of coatings on steel is costing the Air Force more than $50 million 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 was sent to all Air Force bases requesting their coating failure experience. This was followed by selected onsite inspections. The laboratory phase began 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 follow the completion of this study.

Effect of Temperature and Humidity on UF Foams

Walter J. Rossiter, Jr.
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Structures and Materials Division

Sponsor: Tri-Services Committee

Urea-formaldehyde-based foam insulations are being used in greater quantities in the United States in both new and existing housing. In reviewing the performance of these insulations, CBT identified potential problems involved in their use including low resistance to a combination of high temperature and high humidity. Based on preliminary laboratory tests, CBT recommended that, until further data are available, urea-formaldehyde-based foams should not be applied in areas such as attics that may be subjected to prolonged periods of high temperature and humidity.

Under this project, foam specimens will be exposed to various conditions of temperature and humidity in environmental cabinets. Their performance during exposure will be evaluated by observing changes in physical properties such as appearance, weight, and dimensions. Exposure conditions will be chosen to be comparable to those expected during service in geographic locations subject to prolonged periods of high temperature and humidity. The resistance of foams to high temperature and humidity will be investigated using analytical techniques such as thermal mechanical analysis, thermogravimetric analysis, and gas chromatographic analysis of decomposition products. The results of these analytical investigations will be compared with the performance of foams exposed in environmental cabinets. Changes in cellular structure of foams caused by exposure to temperature and humidity will be investigated using photomicroscopy.

Properties of Elastomeric Roofing Membranes

Robert G. Mathey
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Structures and Materials Division

Sponsor: Department of Defense

From a recently completed study, NBS TN 972, *Elastomeric Roofing: A Survey,* it was noted that data are not available on the properties of elastomeric membranes with regard to exposure conditions and aging. It is believed that some elastomeric roofing membranes will exhibit a change in properties when subjected to various exposure conditions and with age. As an example, the level of performance with regard to the weather resistance of elastomeric membranes has not been established. Some factors included in weather resistance are accelerated aging, natural aging, brittleness, dimensional stability, heat aging, ozone resistance, pollutants, volatile loss, loss of plasticizer, and the effects of moisture and temperature. Some membranes may become brittle under cold conditions and have less resistance to tension, impact, and punching shear forces. Aging may appreciably reduce some properties of membranes, particularly when combined with cold environmental conditions. Sustained stress may also reduce the membrane's ability to perform satisfactorily over its intended service life. Because of economic conditions and materials availability the use of elastomeric roofing systems has increased considerably over the last few years. This project will develop information that can be used as a basis for standards and specifications to predict the performance of these systems.

NDE of Moisture in Roofs

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Structures and Materials Division

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.

Under this project, the moisture contents of laboratory-prepared and controlled roofing systems will be determined with nondestructive techniques and compared with the results of moisture determinations made by gravimetric measurements. The moisture contents of different types of roofing systems will be determined using various nondestructive evaluation techniques such as nuclear radiation, electrical capacitance, electrical resistivity, microwave, infrared photography, and infrared thermography.

Performance of Roofing

Robert G. Mathey
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Structures and Materials Division

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.

Under this project, the thermal shock factor, an expression for estimating the resistance of membranes to splitting because of a sudden drop in temperature, will be revised to incorporate a term dealing with membrane extensibility. Available experimental data will be analyzed and used to ascertain the validity of the new mathematical model containing the extensibility term. As part of an ASTM activity under CBT leadership, two major laboratories have conducted tests to measure uplift resistance of comparable roofing systems. A third laboratory will conduct tests to obtain additional data to select and develop a standard method of test. CBT will draft the proposed standard method of test for submission to ASTM.

Two other reports, dealing with the factors influencing bitumen temperatures during construction of built-up roofing membranes and the mechanical properties of built-up membranes, will be published. Performance tests and criteria for roofing systems will be obtained from other countries and summarized in a report to RILEM Committee 31-PCM on Performance Criteria for Building Materials.

Durability of Coatings for Steel

Larry W. Masters
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Structures and Materials Division

Sponsor: National Bureau of Standards

Protective coatings for the steel and wood used in buildings cost 4.5 billion dollars each year. One way to reduce the costs of painting steel structures involves increasing the painting cycle but this is hampered by the lack of reliable methods for predicting long-term performance. 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. A Technical Note was published describing the application of the methodology for the prediction of the durability of coatings for steel. Laboratory research is being performed that will result in improved understanding of adhesion of coatings, and to improved testing procedures. Recommendations will be sent to ASTM on methods to test the durability of steel coatings.

Roofing and Coating Research for the Army

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Structures and Materials Division

Sponsor: U.S. Army

U.S. Army buildings vary widely in construction type and are located in many geographic and climatic areas. Since roofing and coatings have been the source of many of the Army's maintenance problems, this project offers an opportunity to apply laboratory research studies and practical field experience to the solution of special problems. Recommendations will be made about 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 coating failures.

White House Painting Study

Paul G. Campbell
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Structures and Materials Division

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.

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

Organic Coatings

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Structures and Materials Division

Sponsor: Tri-Services Committee

The annual costs of organic coatings in the U.S. exceed $8 billion. 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 Tri-Service Committee's Paints and Protective Coatings Manual will undergo revision and will include sections on legislative restrictions on paint components, surface preparations, and a matrix table on paint compatibilities. Also, advisory and consultative services, based upon laboratory and field tests, will be performed. Reports will be published on a military specification for high performance flat latex, specifications for one-package latex block fillers, and specifications for a heat-resistant coating for steel.

United States-Canada Project for Monitoring Exposure Conditions

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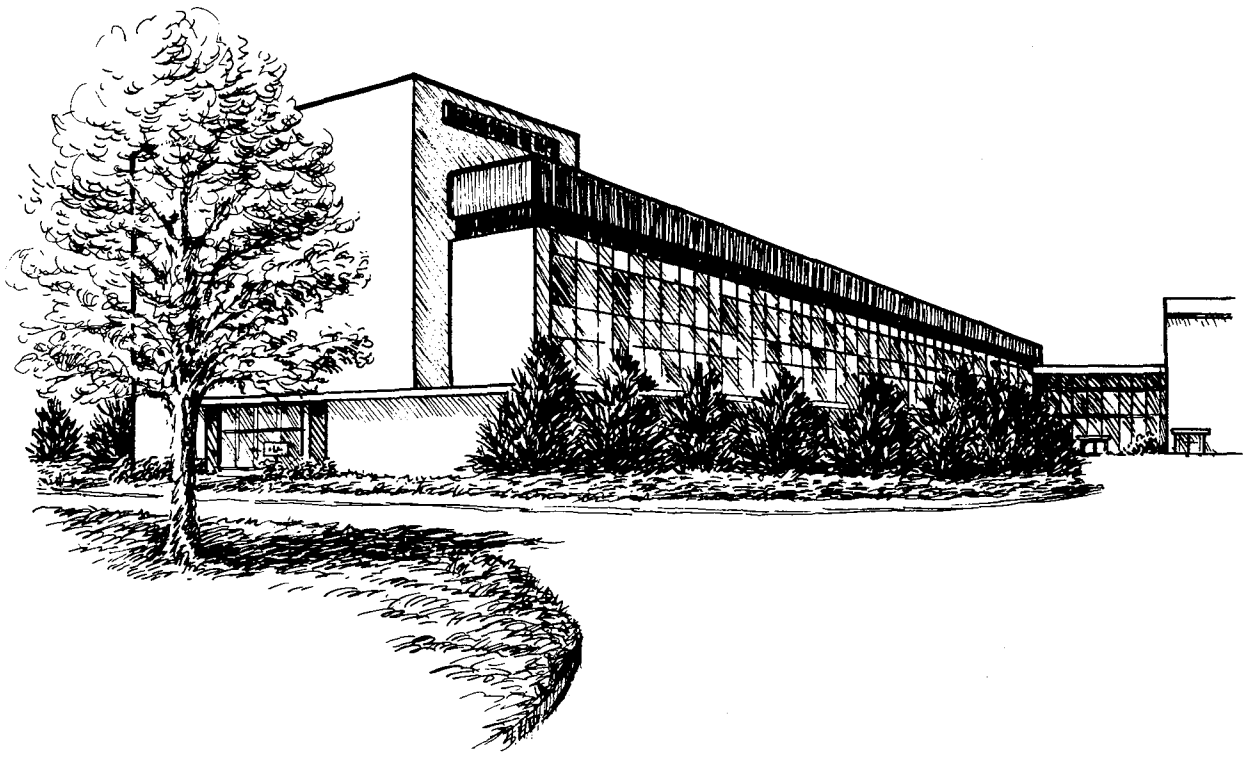
Structures and Materials Division

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 cannot 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 has identified candidate materials and checked their linearity of response to radiation in the laboratory. The sensitivity of the materials to factors other than sunlight is also being determined. Candidate materials are being exposed at CBT and NRC sites and calibrated against instrumental measurements of total and UV radiation. This year's products include a report on the U.S./Canadian study of plastic materials as monitors of solar radiation with recommendations for standardization of materials and measurements. Recommended ASTM and ISO standards for radiation monitoring using plastic materials will also be published.

Building Service Systems Performance



Electrical Distribution Systems Protection

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Building Thermal and Service Systems Division

Sponsor: National Bureau of Standards

NFPA fire statistics indicate that electrical failures cause the largest number of building fires. Annually, about 100,000 fires are attributed to building electrical systems and 60,000 additional result from motors and appliances. CBT laboratory results demonstrate that common overcurrent protection devices do not provide adequate protection against fire during short-circuits. This project will approach this problem through a study of short-circuit phenomena under the range of conditions common in residential wiring. Performance criteria for fire protection requirements of overcurrent protection devices will then be developed. The potential of microprocessors to perform safety functions by recognizing the characteristic signals of short-circuits will also be explored.

Innovative Electrical Wiring

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Building Thermal and Service Systems Division

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 used in building construction until certain performance criteria have been met. 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 electric shock are being characterized with appropriate electrical and thermal measures. After developing a basic understanding of the technical parameters involved, performance criteria and test methods will be developed. Based on the results of this research, changes in the National Electrical Code and changes to other codes and standards will be proposed. Data and information will be provided to groups such as NCSBCS, IEEE, NEMA, and ANSI.

Air and Smoke Migration in Buildings

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Building Thermal and Service Systems Division

Sponsor: National Bureau of Standards

A major cause of fire casualties is smoke inhalation by building occupants. Analytical procedures for predicting smoke migration as a function of building construction, HVAC system operations, climatic factors, and occupancy schedules are sorely needed. This project will attempt to fill this analytical gap, providing a computer program that can be used to study air and smoke motion through interior doors, staircases, and HVAC ducts. This year the project will develop a comprehensive algorithm suitable for the simultaneous solution of heat, air, and smoke transfer equations. Several other novel computing schemes are also to be studied.

Plumbing Systems Measurement and Design Methods

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Building Thermal and Service Systems Division

Sponsor: National Bureau of Standards

The plumbing community has identified the need for revision of storm drainage systems design criteria as a result of new weather-load data. Present storm drainage systems are thought to be oversized and wasteful of piping materials. Likewise, the VA has asked CBT to provide assistance for its hospital plumbing systems studies with emphasis on reduced size venting (RSV). The study of the dynamics of RSV requires a sophisticated testing environment and measurement capability that can only be satisfied by the CBT Plumbing Research Laboratory.

A flow-visualization inlet tank and flow control provides for tests with a variety of pipe sizes, entrance configurations, and vortex strengths. The microcomputer will interface directly with the storm drain data collection, and data reduction activities. The CBT minicomputer will continue to provide support with graphic interpretation of reduced data. State-of-the-art instrumentation, including the laser anemometer and microcomputer, for determining capacity and falling-film velocity in stacks will be applied. Straight stack tests for 50 mm and 100 mm (2 and 4 in.) pipe sizes will be completed and turning offset sections will also be studied. Dynamic measurement capabilities to monitor hydraulic tests of VA plumbing installations and the long-run header/stack tests will be continued and header bend tests begun.

Service Systems Demand Modeling

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Building Thermal and Service Systems Division

Sponsor: National Bureau of Standards

Using waste water and reject heat can lead to a significant reduction in the energy and water requirements in buildings. Products are currently being introduced to recover this heat from air conditioners, waste water, and heating system flues. But the evaluation of these products and methods requires service system demand models. Under this project, operational models, under household usage, of air conditioners and refrigerators will be developed. Use of waste heat by several types of heat recovery devices will be studied using the field data from the Twin Rivers Appliance Studies, the Andrews AFB water and water-heater study, and the building satellite loads of the Total Energy Project at Jersey City. A parametric study of the design factors for several heat recovery devices will then be undertaken. The results of all this, computer programs and data sets for evaluting heat-recovery systems, will be published as NBS reports.

Performance of Water Conserving Devices

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Building Thermal and Service Systems Division

Sponsor: Department of Housing and Urban Development

Today, many methods and devices for reducing water use are being recommended and promulgated by local and state regulatory bodies without a technical basis for their performance requirements. Because of this problem, CBT is designing a set of test methods for such devices and is determining a rating method from these test results to supply designers, contractors, inspectors, and building regulatory officials with economically efficient guidelines and criteria. Both user acceptance of water reduction and sanitary requirements for public health are at stake. Especially important will be studies of water transport of wastes in partially filled drainage pipes.

VA Hospital Plumbing Criteria

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Building Thermal and Service Systems Division

Sponsor: Veterans Administration

In this project, full-scale vent stack and header tests will be instrumented in the Plumbing Research Laboratory with high-speed data acquisition components coupled to the 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 of 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 to journals. Overall, incorporation of RSV systems in Veterans Administration hospitals could result in large cost savings within two years.

Underground Heat Distribution Systems

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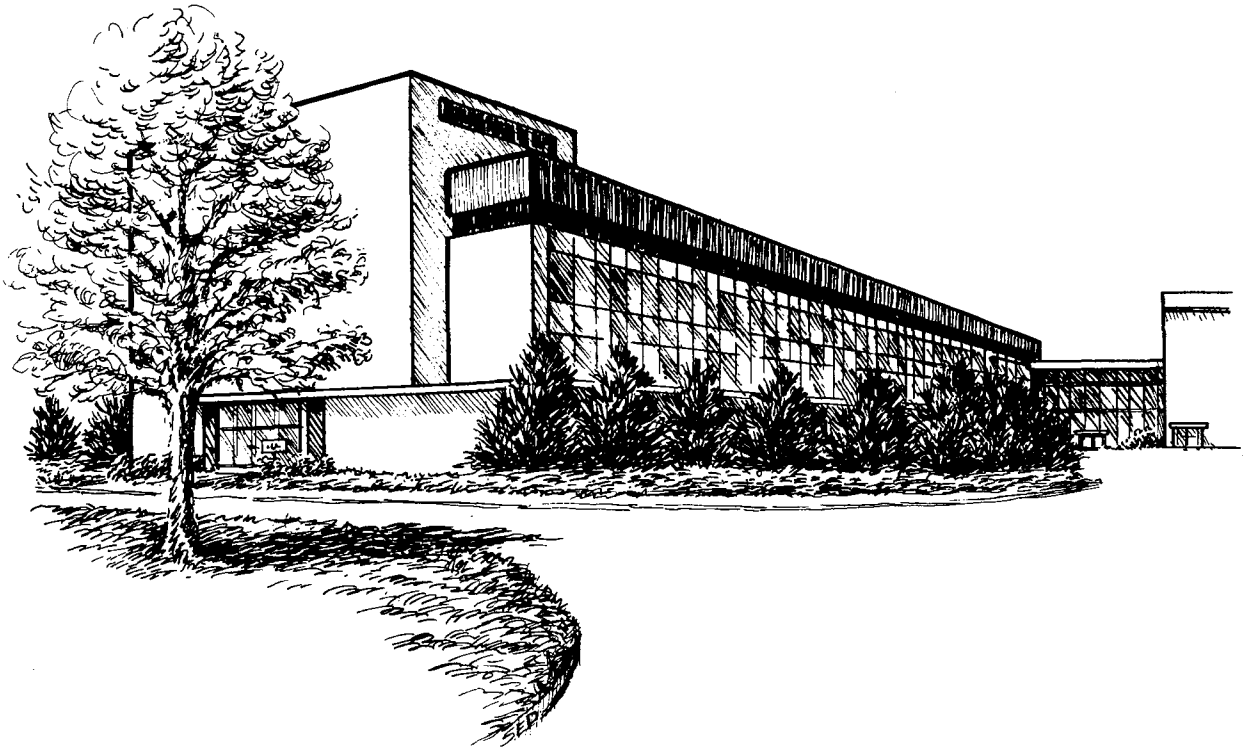
Building Thermal and Service Systems Division

Sponsor: Department of Defense and Tri-Services Committee

Although underground heat distribution systems are often considered in the energy conservation plans of communities, many of the existing systems have been failing due to ground water seeping into the system and the rupture of the carrier pipes. Under this project, a prototype testing facility will be constructed for evaluating the pipe heat loss while ground water is allowed to enter under laboratory conditions. Underground heat distribution systems of selected categories and types will be tested to validate the Tri-Services test criteria.

Environmental Design Technology



Task Lighting Criteria

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Environmental Design Research Division

Sponsor: Department of Energy

Designers increasingly question the validity of the current North American recommendations for levels of illumination. CBT studies 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. The data currently available are serving as the basis for a paper describing the laboratory research approach and applications to lighting design. But the major product of this project will be the development of a more realistic basis for the development of lighting energy criteria for buildings.

Illumination Measurements and Criteria

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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 today's illumination levels is being seriously challenged, and often rejected, by practitioners in the field, but no sound methodology is available to replace it. A key element required is the provision of precise, valid physical measurement techniques, widely accepted in the field, to provide the foundation for vision research, guide systems design, and evaluate the effectiveness of installed systems. This project will approach the problem through a physical measurement laboratory, where precise physical measurements can be developed under controlled conditions. This facility will also enable bi-directional reflectance to be measured for a variety of standard tasks. Another product of the work will be a set of reproducible standard targets, available for wide use in the field.

Visual Environment

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Sponsor: National Bureau of Standards

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. Such an instrument, called a visibility meter, will be designed and constructed this year; it will become an important part of this continuing research. 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 Techniques in NDE

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Sponsor: National Bureau of Standards

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 parameters associated with typical NDE sites and tasks will be conducted. In this project for NBS's National Measurement Laboratory, microphotometric and microdensitometric measurements will be made of NDE tasks encountered in practice. The 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.

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.

A major task this year will be the study of the conspicuity of warning lights, such as might be used for emergency signals in and around buildings. The idea is to permit any signal light to be given a numerical rating on a common, standardized scale that represents people's reactions. Ultimately, performance specifications for such lights could be expressed simply as a minimum rating on this conspicuity also begin on an experiment to assess color contrast as a function of field size. The experiment will be an instrumental, continuously variable generalization of a study done with fixed paper samples by Judd and Yonemura. Output of this project will be a report describing the methodology of the experiment for the quantitative scaling of the conspicuity of lights, as well as the experimental findings for the dependence of conspicuity on luminosity, flash rate, and their interaction. Two publications based on work from earlier years are planned: a book chapter on specification and designation of color and a paper on formulas for predicting the equivalent luminance of colored lights (i.e., the luminance of an equally bright white light).

Site Development

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Sponsor: National Bureau of Standards

Current site development practices result in high costs while failing to ensure high-quality performance in a number of critical areas. HUD and others have singled out site development costs as the fastest growing segment of housing costs and the segment with the greatest potential for cost reductions. At the same time, most existing site regulations lack substantiating documentation and do not effectively promote energy efficiency, building security, or even occupant and pedestrian safety. Potential for improvement in voluntary design practices and in regulations is suggested by recent research on building security, consumer acceptance, and pedestrian safety. Substantial improvement in energy conservation is demonstrated by the success of recent innovative amendments to zoning ordinances in Davis, CA, in which passive solar design principles are incorporated into subdivision requirements.

This project is developing an overview report on current U.S. site development regulation, its effectiveness and its costs, and the institutions involved with it. Issues are: the types of site regulation in effect, their extent and the nature of their mandates; the physical characteristics of building sites addressed by regulation, the purposes of regulation, and the range of prescribed values found in codes; institutions involved in site regulation and mechanisms by which regulations are modified; and impacts of current site regulation on building costs, both the process costs (primarily due to delay) and compliance costs (building measures to meet the regulations). The report will be used in planning NBS research on site development.

Design Technology Development

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Sponsor: National Bureau of Standards

The purposes of this project are to consider: (1) information networks in the design professions, (2) the role of the Environmental Design Research Division (EDRD) in serving the design professions through research activities, and (3) the challenge of matching the multidisciplinary capabilities of the problems. The approach to dealing with these issues involves a series of roundtable discussions designed to contribute to the EDRD's short and long range planning.

Building Circulation

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Sponsor: National Bureau of Standards

Pedestrian circulation is a critical factor in the design of buildings. The location and association of spaces in buildings determine the pattern and characteristics of pedestrian circulation and therefore have a direct effect on the building's economy. This project will: 1) analyze pedestrian movement characteristics on building ramps and relate the findings to pedestrian movement characteristics on such as stairs and corridors; and 2) develop a conceptual framework that both classifies and defines the elements of pedestrian circulation in buildings. Later phases of the project will characterize frequently

encountered circulation problems, and develop models of pedestrian circulation.

Interior Space Criteria

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Sponsor: National Bureau of Standards

Energy conserving illumination and daylighting schemes, new designs in office furnishings, and the proliferation of the "open plan" office layouts are all challenges to the interior space planner. Under this project, a literature review of office planning will be a basis for determining how space planning criteria are developed and used in office design. A conceptual framework, consistent with environment/behavior research, will be prepared to help develop or make explicit space planning criteria and to rationalize office evaluation studies. A pilot study of a space planning concept is underway to assess the feasibility of the proposed approach. There will be interviews with the General Services Administration and other federal staff involved with space planning and with officials of professional societies of space planners: American Society of Interior Designers and Institute of Business Designers.

Post-Occupancy Evaluation Techniques

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Sponsor: National Bureau of Standards

Many buildings today do not appropriately serve their intended functions. While ad hoc studies of post-occupancy evaluation are performed, no systematic approach exists at present to evaluate buildings. As a result, the present state-of-the-art dealing with this subject is inadequate, being little better than it was decades ago. The improvement of building design requires a better understanding of design factors that do and do not work, and the development of a standardized evaluation procedure (linked to the design process). This project will undertake a review of research procedures and studies concerned with the evaluation of buildings. Field studies of buildings will be conducted to develop, test, and improve a model of post-occupancy evaluation. The model will focus on the influence of design decisions on the functional adequacy of buildings from the standpoint of occupant activities.

Design and Construction Technology Application Program

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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 problems to be answered and as a continuing resource during the research. Research findings and other technical information will be converted as necessary into forms usable by the design and construction communities. Last year, project results in acoustics, windows and energy, design economics, architects' access to information, and home safety were presented in several media. These and other forums will be used again this year to bring researchers and practitioners to a common awareness of building problems and the tools needed, or at hand, to solve them.

Federal Building Technology

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Sponsor: National Bureau of Standards

This project assists CBT in performing its mission to increase the usefulness, safety, and economy of buildings by disseminating research findings to the federal agencies, building owners, designers, builders, users, and others in the building community. This project also contributes to assessing the technical trends, needs, and concerns of the building community and determining the kind of technical information that is needed from CBT.

During this year, this project will publish technical material on CBT's research activities to notify building community users about ongoing and completed research, conduct workshops and seminars on building science and technology, and complete the design and installation of a centralized computer facility to improve data analysis in the CBT laboratories.

Services to the Federal Construction Council

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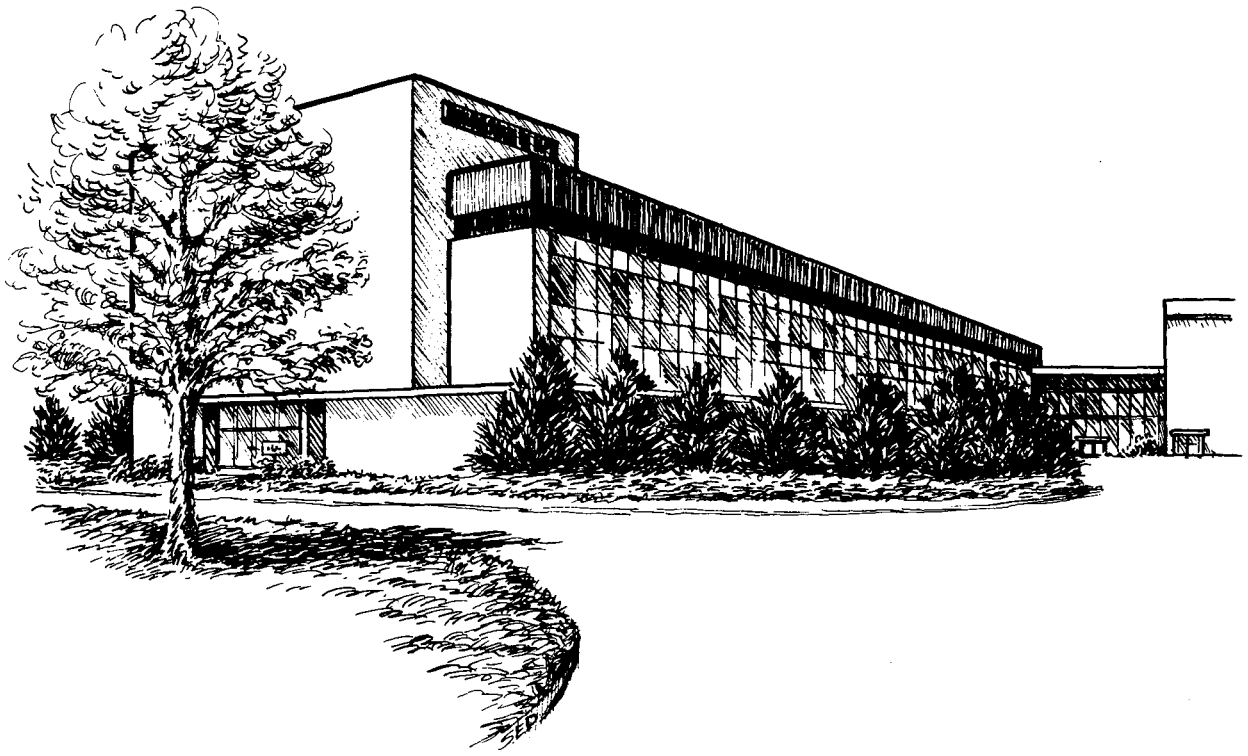
Sponsor: Several Federal Agencies

The Federal Construction Council (FCC) is a special element of the Building Research Advisory Board, Commission of Sociotechnical Systems, National Research Council. Its purpose is to foster continuing cooperation among the Federal Construction agencies in advancing science and technology as related to design, construction, and operation of Federal facilities. Under this project, CBT will contribute to the FCC *Newsletter, Transactions of the Federal Construction Council,* Federal Construction Guide Specifications, and a number of administrative reports.

Building Economics



Techniques for Economic Evaluation

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Sponsor: National Bureau of Standards

Because of the rising costs of building materials, the increasing cost of construction due to safety and environmental requirements, and the rising costs of clean water and fuels, the building community continues to need more sophisticated economic tools for evaluating alternative building technologies and financing mechanisms to help provide affordable buildings. The aim of this project is to foster the use of benefit-cost techniques in building design evaluations. Among other studies this year, CBT economics research will support the development of an ASTM standard. A life-cycle cost guide, in condensed form, will be published in *Architectural Graphic Standards.* Reports will also be published on rehabilitation and fire, incorporating simulations and econometric models.

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.

Under this project, disposal cost data gathered by a 1975 NSF study will be used to calculate solid waste densities. They will also be ranked and correlated with each of the major cost components of the system (labor, vehicle operating costs, etc.) as well as total collection costs. If there is sufficient variance in density and small correlation between weight and volume, then regression analysis will be used to estimate a cost function based on weight and volume.

Estimating Area Cost Factors

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Sponsor: Tri-Services Committee

The lack of accurate and reliable area cost factors (ACFs) is a serious problem to the Tri-Services in the estimation of building construction costs. Area cost factors convert unit construction costs from different geographic regions to a common base; they are used by Tri-Services, the Secretary of Defense, and Congress during the approval and review process of all Tri-Services construction projects. Information from completed Tri-Services construction projects and economic data such as regional/local construction market data will be used to develop a geographic cost

index. The index will be developed so that it may also be used by Tri-Services to estimate ACFs for selected foreign areas. The results of this research, and of the Michigan State University research on geographic cost differentials on military construction, will be delivered as a report to Tri-Services.

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