1982-1983 BUILDING TECHNOLOGY PROJECT SUMMARIES

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FOREWORD

The building research program of the National Bureau of Standards, the Nation's central engineering measurements laboratory, is conducted by its Center for Building Technology (CBT). CBT performs field, laboratory, and analytical research to provide knowledge on the properties of whole buildings and building materials, components, and systems, and on measurement techniques to evaluate these properties. This knowledge is needed for responsible and cost-effective decisions on the building process and cannot be obtained through proprietary research and development.

Construction is one of the Nation's largest industries. It amounted to about $238 billion, 8 percent of the GNP, in 1982. Sixty-nine percent of the Nation's wealth, $5,300 billion, is invested in constructed facilities that shelter and support almost all human activities. Effective building decisions require sound technical bases. CBT is the only comprehensive, non-proprietary laboratory in the U.S. dedicated to meeting the measurement needs of the building community. The term "building community" describes the groups responsible for the design, construction, and operation of constructed facilities. These include owners, manufacturers, designers, financiers, developers, contractors, craftsmen and laborers, educators, research and testing laboratories, standards developing organizations, and regulatory agencies of state and local governments.

CBT research provides knowledge for decisionmaking. This knowledge includes characterization of the environments in which buildings must operate (such as snow loadings to be anticipated during the service life), characterization and definition of the performance of buildings, components, and systems (such as the mechanisms for heat loss through a window or wall cladding element), and methods of testing for performance qualities that will apply equitably to a whole family of potentially competitive proprietary materials and components.

The CBT staff of 150 includes 100 professionals, of whom 34 are registered professional engineers or architects and 50 hold the Ph.D. degree. The principal disciplines are structural, geotechnical, materials, electrical and mechanical engineering, physics, and chemistry.

The Center's specialized laboratory facilities and equipment located at Gaithersburg, Maryland, have a replacement value estimated at $20 million. Among the variety of special facilities and equipment are the universal testing machine with a 12-million-pound capacity; a reaction wall for subjecting full-scale building systems to earthquake loading; seven environmental chambers, including a 30 x 40 x 60 ft chamber, for evaluating the thermal performance of buildings and components; a line heat source guarded hot-plate to characterize insulation to 12 inches thick; a calibrated hot-box test facility; a five-story plumbing research laboratory; reverberation and anechoic chambers; lighting

research facilities; mobile laboratories; an outdoor solar-collector test-method development area, including a passive solar test house; a network of outdoor exposure sites; a scanning electron microscope and other instruments for material characterization; facilities for experiments on solar heating and cooling systems; and controls and equipment laboratories.

This report summarizes CBT's research for 1982-1983. Each summary lists the project title, its progress, point of contact within CBT, and sponsor. The summaries are arranged according to the research areas that cover the scope of work at CBT. The reader is encouraged to review a companion document: NBS Special Publication 457, Building Technology Publications, and its supplements. Final reports on the projects described here will be listed in future issues of that document.

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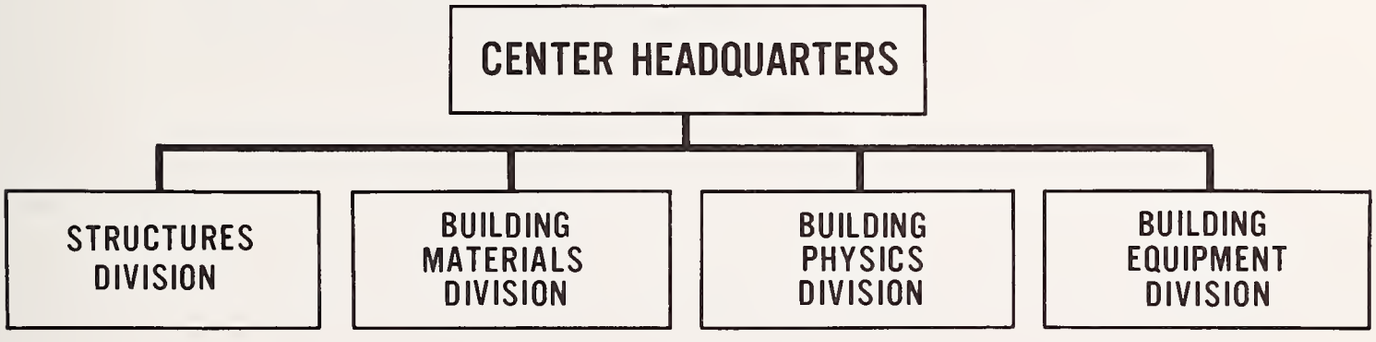
ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ABBE	Advisory Board on the Built Environment
ACI	American Concrete Institute
AIA	American Institute of Architects
AMRL	AASHTO Materials Reference Laboratory
ANSI	American National Standards Institute
ARI	Air-Conditioning and Refrigeration Institute
ASCE	American Society of Civil Engineers
ASSE	American Society of Sanitary Engineers
ASTM	American Society for Testing and Materials
ASHRAE	American Society for Heating, Refrigerating, and Air-Conditioning Engineers
ASME	American Society for Mechanical Engineers
BECC	Building Energy Conservation Criteria
BEPS	Building Energy Performance Standards
BLAST	A Computer Program Dealing with Building Energy Loads
BNL	Brookhaven National Laboratory
BOCA	Building Officials and Code Administrators International, Inc.
BOM	Bureau of Mines
BSS	Building Science Series
BUR	Built-up Roofing
CABO	Council of American Building Officials
CAD	Computer-Aided Design
CBT	Center for Building Technology
CCC	Codes Community Committee
CERL	Construction Engineering Research Laboratory (U.S. Army)
CIB	International Council for Building Research, Studies, and Documentation
CICC	Construction Industries Coordinating Committee
CIE	International Commission on Illumination
CSA	Community Services Administration
CPSC	Consumer Product Safety Commission
DoD	Department of Defense
DoE	Department of Energy
EIA	Energy Information Agency
EMCS	Energy Monitoring and Control Systems
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FCC	Federal Construction Council
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FHWA	Federal Highway Administration
FPL	Forest Products Laboratory
GSA	General Services Administration
HHS	Department of Health and Human Services
HUD	Department of Housing and Urban Development
HVAC	Heating, Ventilating, and Air-Conditioning
ICBO	International Conference of Building Officials
IEEE	Institute of Electrical and Electronic Engineers
IERI	Illuminating Engineering Research Institute
IES	Illuminating Engineering Society
IESNA	Illuminating Engineering Society of North America
ISO	International Standards Organization
LANL	Los Alamos National Laboratory
LBL	Lawrence Berkeley Laboratory
NAHB	National Association of Home Builders
NBS	National Bureau of Standards
NBSIR	National Bureau of Standards Interagency Report
NBSLD	National Bureau of Standards Load Determination (A Computer Program)
NCSBCS	National Conference of States on Building Codes and Standards
NDE	Nondestructive Evaluation
NIBS	National Institute of Building Sciences
NIOSH	National Institute of Occupational Safety and Health
NML	National Measurement Laboratory

NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRC	Nuclear Regulatory Commission
NRCC	National Research Council (Canada)
NSF	National Science Foundation
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration
PBS	Public Buildings Service
PBS/BSP	PBS Building Systems Program
PMMA	Polymethylmethacrylate
PVC	Polyvinyl Chloride
RILEM	International Union of Testing and Research Laboratories for Materials and Structures
RSV	Reduced-Size Venting
SAE	Society of Automotive Engineers
SASE	Standards Analysis, Synthesis, and Expression Software
SERI	Solar Energy Research Institute
SPT	Standard Penetration Tests
SRM	Standard Reference Materials
UBC	Uniform Building Code
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



- Structural Engineering
- Geotechnical Engineering
- Earthquake Hazard Reduction
- Construction Safety

- Organic Materials
- Inorganic Materials
- Cement Hydration
- Materials Reference Laboratories

- Thermal Analysis
- Thermal Measurements
- Thermal Insulation
- Acoustics
- Illumination Engineering

- Thermal Machinery
- Mechanical Systems and Controls
- Combustion Equipment
- Solar Equipment

STRUCTURAL ENGINEERING

Criteria for Structural Loads and Design
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Dependence of Extreme Wind Speed Upon Direction
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Reliability-Based Design of Containments and Category I Structures
Dynamics and Reliability of Compliant Drilling and Production Platforms
Assessment of the Uncertainties and Risk Associated with the Dynamic Behavior of Compliant Offshore Structures

CRITERIA FOR STRUCTURAL LOADS AND DESIGN

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Sponsor: National Bureau of Standards

Current structural 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 design philosophy 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 toward the 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.

This project is concerned with developing design criteria for use in building standards that will ensure adequate reliability against structural failure and unserviceability. This will lead to reduced building costs by simplifying the design process and stimulating market competition between construction technologies. Improved serviceability requirements would result in less maintenance and increased occupant satisfaction. This research will be valuable to national standards organizations and to Federal agencies charged with developing criteria for reliability and serviceability of building structures. These include the HUD Minimum Property Standards and ANSI A58 (Minimun Design Loads in Buildings and Other Structures).

CRITERIA FOR DESIGN OF CLADDING SUBJECTED TO WIND LOADS

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Sponsor: National Bureau of Standards

Modern analytical and experimental tools have not yet been used in investigating the reliability of cladding subjected to wind loads. Tools from the fields of wind engineering (aerodynamics of bluff bodies in turbulent boundary layer flows), nonlinear mechanics of plates, structural reliability, and materials testing will be used in this project with a view to developing rational criteria for cladding design. Data from full-scale and wind-tunnel investigations of wind loads on cladding will be reviewed and studies will be conducted to determine additional research needs.

This year, the project will develop an NSF proposal on glass behavior under wind loads, and will compare failure statistics using empirical criteria versus correct wind engineering approaches. Another output will be a study of how fluctuating loads affect failure statistics. Successful completion of this project could save money and reduce accidents that result from unsafe cladding. Other savings could result by preventing the overdesign of cladding in instances where conservative design provisions prevail.

CRITERIA FOR WIND TUNNEL MODELING

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Sponsor: National Bureau of Standards

This project will support the development of operational criteria and preliminary planning of aerodynamic and structural design of a CBT boundary-layer wind tunnel. Facility design will be based in part on test data obtained from previous studies carried out on a 1/4-scale model of the proposed tunnel. When completed, the tunnel will enable CBT to address important problems in several areas of building technology. In addition to providing new opportunities for research, this facility will enable CBT to more effectively respond to the research needs of Federal agencies such as DOE, FHWA, GSA, and HUD. The recently published proceedings of the international wind tunnel workshop held at NBS in April 1982 is expected to influence modeling techniques both here and abroad.

DEPENDENCE OF EXTREME WIND SPEED UPON DIRECTION

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Sponsor: National Science Foundation

Current procedures for estimating wind loads take into account the dependence of aerodynamic coefficients upon the direction of the wind speeds. However, no account is taken of the dependence upon direction of the extreme wind speeds expected to act on the structure during its lifetime. For this reason, reliability levels can vary significantly among wind-sensitive components of the same structure. In this project, a statistical procedure for estimating wind loads that may be expected to act on structures during their anticipated life will be developed, in which wind directionality effects will be taken into account. The procedure consists of creating scalar time series of the extreme wind pressures and inferring design wind speeds through statistical analysis.

The procedure will be adopted for use in hurricane-prone regions, where special statistical methods for describing the wind climate must be used. Advantage will be taken of previous CBT experience with such methods. The reliability of structures whose orientation is not known in advance will be estimated by taking wind directionality into account, with a view to developing procedures for developing risk-consistent code provisions for wind-sensitive structures. Information on dependence of extreme winds upon direction obtained by the National Climatic Center (NOAA) within the framework of this project will be published for use by structural designers.

PROBABILISTIC RISK ASSESSMENTS OF TORNADO MISSILE DAMAGE

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Sponsor: Nuclear Regulatory Commission

Among the possible causes of damage to nuclear power plants is the impact of objects, referred to as missiles, that are propelled by tornado winds. The Nuclear Regulatory Commission specifies that the probability of tornado-borne missiles attaining critical speeds and hitting nuclear power plants must not exceed 10^{-7} in any one year. Whether or not this is the case, it should be verified before the approval of any particular nuclear power plant. This project is concerned with assessing a verification carried out by Bechtel Corporation for the spray nozzles of the ultimate heat sink in the Palos Verde Nuclear Generating Station, and the general methodology for estimating tornado-borne missile risks proposed in the report, "Tornado Missile Simulation and Design Methodology." The assessment is carried out using probabilistic, statistical, and numerical simulation tools, as well as information concerning frequency of occurrence and physical characteristics of tornadoes, and aerodynamic characteristics and potential number and location of objects susceptible of becoming tornado-borne. This work will assist NRC in ensuring acceptably small risks of accident in the operation of nuclear power plants.

RELIABILITY-BASED DESIGN OF CONTAINMENTS AND CATEGORY I STRUCTURES

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Sponsor: Brookhaven National Laboratory

The unpredictable nature of the possible loads on nuclear power structures, as well as uncertainties in structural properties and behavior, suggest a probabilistic approach for an assessment of structural safety and performance. This means that safety and performance should be determined according to acceptable levels of risk or required levels of reliability. Structural reliability theory already has been applied to earthquake engineering, wind engineering, ocean engineering, aerospace structures, and in the development of load factors, load combinations, and resistance factors for practical design.

In the nuclear industry, there has also been an increasing trend toward the use of statistical analysis and probability theory for safety evaluations. This is particularly the case for seismic Category I structures for which rational methods for reliability evaluation of strength and loads are urgently needed. This new reliability-based design approach has a number of significant advantages. It can be expected that structural designers and regulatory authorities will take advantage of these methods if they do not lead to significant additional complexities at the design level.

Under this joint project, CBT will have responsibility for the analysis of service and extreme environmental loads and for developing the basic load combination methodology. BNL will have responsibility for analyzing accidential loads, postulating accident scenarios, dynamic structural analysis of the nuclear structures, and testing the design procedure.

DYNAMICS AND RELIABILITY OF COMPLIANT DRILLING AND PRODUCTION PLATFORMS

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Sponsor: United States Geological Survey

According to published estimates, costs of conventional fixed offshore platforms are prohibitive in deeper waters, where compliant structures become economically justified. These estimates indicate that guyed tower systems are economical for water depths within the approximate range of 1,000 to 1,600 ft, whereas the use of tension-leg platforms becomes economical for water depths in excess of about 1,600 ft. Because the behavior of a compliant structure in a marine environment is complex, the evaluation of its performance can pose difficult problems to regulatory agencies. The purpose of this study is to create a basis for understanding the behavior of complaint structures and estimating their reliability during construction and service. The study will include the gathering and evaluation of information on proposed designs, identification of topics needing research, and research on critical topics. The results of this work will make possible the design of the most reliable and cost-effective platforms possible.

ASSESSMENT OF THE UNCERTAINTIES AND RISKS ASSOCIATED WITH THE DYNAMIC BEHAVIOR OF COMPLIANT OFFSHORE STRUCTURES

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Sponsor: Minerals Management Service

The purpose of this study is to employ information on various proposed designs to list limit states that may occur as a result of the dynamic behavior of compliant offshore structures, and apply modern structural reliability techniques to the estimation of nominal failure probabilities of such structures and the assessment of their structural safety. For selected compliant offshore structural types, this project will provide detailed mathematical models of the limit states that may occur as a result of their dynamic behavior under wind and wave action.

Researchers will review fundamentals, practical methodologies, and computer programs pertaining to structural reliability, will obtain suitable computer programs for estimation of failure risk based on Monte Carlo simulations, and maintain close contact with the American Bureau of Shipping, Det Norske Veritas, Navy Department, and other agencies with an interest in structural reliability of compliant offshore structures.

GEOTECHNICAL ENGINEERING

Geotechnical Measurement of In-Situ Soil Properties
In-Situ Measurement of Soil Properties by Thermal Methods
In-Situ Measurement of Soil Properties by Acoustics
Cyclic Strain Approach to the Determination of Liquefaction Potential of Level Sandy Sites
Gage for Measurement of Dynamic Soil Stress

GEOTECHNICAL MEASUREMENT OF IN-SITU SOIL PROPERTIES

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Sponsor: National Bureau of Standards

The key to ensuring the stability of structures, utilities, and construction sites lies in our ability to accurately characterize soil behavior. Since soil is not a man-made material, its successful characterization depends on its properties in the undisturbed state in the ground. Under this project, tests will be conducted with the acoustic cone and correlated with other in-situ and laboratory soil tests. From these data, the methodology for in-situ measurement with the acoustic cone will be developed.

Design curves will be developed for the use of the cone penetrometer for evaluation of the liquefaction potential of sites subjected to earthquake effects. Also, Japanese Standard Penetration Test methodologies and equipment will be studied to provide a better interpretation of existing Japanese subsurface exploration data from sites that experience liquefaction, which are presently used in our design curves for the Standard Penetration Test. This research will lead to new, more reliable, and more efficient in-situ measurement methods. It will reduce the cost of foundations, reduce foundation failures, and increase the feasibility of construction on unstable sites by providing a more reliable assessment of subsurface conditions.

IN-SITU MEASUREMENT OF SOIL PROPERTIES BY THERMAL METHODS

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Sponsor: National Bureau of Standards

The thermal conductivity of soil is significantly affected by soil moisture. The correlation between moisture content and thermal conductivity must be known for accurate predictions of energy dissipation of buried transmission lines and other structures surrounded by soils. Conversely, the correlation between moisture content and thermal conductivity may be used to measure soil moisture content in-situ and to determine the plastic limit of clays in the laboratory.

Under this project, measurement of thermal resistivity and its variation with moisture content and density will be performed on two fine-grained soils, one of a high plasticity, and one of a low plasticity. The concept generated from last year's studies will be tested and expanded. Results will lead to better modeling of heat dissipation in soils and to new methods of in-situ and laboratory measurement of soil properties.

IN-SITU MEASUREMENT OF SOIL PROPERTIES BY ACOUSTICS

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Sponsor: Bureau of Reclamation

Substantial laboratory research has recently been performed at the University of California at Berkeley in the area of identification of soil properties by acoustic methods. When these techniques are combined with a cone penetration device, we gain the capability of identifying, in addition to the shear strength parameters, other soil properties such as soil type, grain-size distribution, coefficients of permeability and relative density. A cone which receives acoustic signals during penetration has already been tested successfully in the laboratory. A more advanced type of cone is now available for experimental research. This new cone will also be able to emit acoustic signals and determine the response. The new cone, which will also be equipped with piezometer, has the capability of substantially advancing the state-of-the-art in in-situ measurements, but substantial field research is necessary before the data can be interpreted and used in engineering practice. This project will carry out coordinated research in the field and laboratory, including correlation studies with other in-situ devices, to develop reliable measurement techniques.

CYCLIC STRAIN APPROACH TO THE DETERMINATION OF LIQUEFACTION POTENTIAL OF LEVEL SANDY SITES

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Sponsor: National Bureau of Standards

Relative density is currently used as the single important parameter in preparing laboratory specimens of sand to model liquefaction potential under in-situ conditions. Research now indicates that many other characteristics of the soil are important such as the manner of deposition, history of preconsolidation, and history of vibration. These are collectively referred to as the soil fabric. At present, two methods are used to predict liquefaction potential of sites. In the first method, Standard Penetration Test results from the site in question are compared with those from sites that liquefied in the past. In the second method, reconstituted samples are subjected to cyclic stress in the laboratory, using again Standard Penetration Test results to determine relative density in the field. This project will determine the correlation between cyclic strain and pore water pressure buildup and volume change for a wide range of granular soils, and develop a new design approach based on these correlations. This research will lead to a new, more reliable method of determining liquefaction potential, cyclic mobility, and seismic settlement of level sandy sites. It will also serve as the basis for further research in geotechnical earthquake engineering.

GAGE FOR MEASUREMENT OF DYNAMIC SOIL STRESSES

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Sponsor: Air Force

The in-situ measurement of stress in a soil mass poses difficult problems because stress gages stiffer than the surrounding soil introduce disturbances that distort the stress field. Also, the traditional method of determining stresses via the measurement of strains does not work well in soils since stress-strain relationships are complex and poorly understood. The problems are magnified in the measurement of dynamic effects, which is further hampered by the poor frequency response characteristics of available gages.

There is an opportunity for advancing the state-of-the-art in this measurement area by the use of piezo-electric polymer material developed by NBS. This material possesses two properties that make its use as a soil-stress gage attractive. The polymer gages can be thin and flexible, minimizing the disturbance in the stress distribution in the soil mass. And also the gages have favorable dynamic response characteristics and could pick up high-frequency puressure pulses.

The development of the gage also poses difficult technical problems, such as uncoupling of stress and adiabatic heat effects, and uncoupling of compressive and shear stresses. If the gage is successful it will be widely used by industry, government agencies, the armed forces, and research laboratories. The gage will also improve the state-of-the-art in soil dynamics by providing an accurate signature of pressure pulses which in the past where not available.

EARTHQUAKE ENGINEERING

Technical Assessment of Earthquake-Resistant Design Provisions
Torsional Effects in Buildings Subjected to Earthquake Excitations
Fatigue Tests in Full-Scale Block Walls
Large-Scale Bridge Columns Subjected to Reversed Cyclic Loading
Cyclic Loading of Masonry Building Components

TECHNICAL ASSESSMENT OF EARTHQUAKE-RESISTANT DESIGN PROVISIONS

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Sponsor: Federal Emergency Management Agency

This project is a continuation of work with the Federal Emergency Management Agency in its effort to support improvements in seismic design criteria. CBT is participating with the Building Seismic Safety Council (BSSC) in conducting its efforts in the private sector and with the Interagency Committee on Seismic Safety in Construction (ICSSC) in its activities with the Federal agencies.

The BSSC is currently evaluating proposed seismic provisions through the conduct of trial designs of buildings using the proposed revisions. CBT is conducting technical studies for the BSSC Trial Design Overview Committee. This work is done in coordination with other members of the Committee who are voluntarily donating their time. Studies include preparation of a plan for the conduct of the trial design program to evaluate the provisions and preparation of the source document used for trial designs. CBT is working closely with the BSSC in all phases of the trial design program.

Working with the ICSSC, CBT develops recommendations for future substantive improvements in Federal seismic provisions. An existing draft standard prepared for trial use by the ICSSC is based on current practice. It is the first step in improving Federal standards, with its primary purpose to introduce a uniform practice among all Federal agencies. Substantive improvements in the Federal seismic provisions for buildings will take several years to accomplish and should be coordinated with the eventual improvement in the private sector that will come about as a result of the BSSC activities.

CBT provides the chairman of ICSSC and of the ICSSC steering group and provides the technical secretariat for ICSSC and its steering group. Additionally, staff members serve on various ICSSC technical committees and provide the chair for the Committee on Building Standards.

TORSIONAL EFFECTS IN BUILDINGS SUBJECTED TO EARTHQUAKE EXCITATIONS

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Sponsor: National Bureau of Standards

The need for providing torsional resistance in buildings subjected to earthquakes is well known. Development of rational criteria for seismic design requires study of the behavior of structural systems subjected to seismic waves. However, the provisions in the current building codes are largely based on engineering judgment. A design eccentricity of five percent of the maximum building dimension is used in the Uniform Building Code and the Recommended Lateral Force Requirements of the Structural Engineers Association of California.

The current investigation emphasizes theoretical analysis. The problem will be formulated by considering all the significant effects, especially soil-structure interactions. Dynamic eccentricity will be determined in the timedomain to represent the level of structural response. Case studies will be made to find the contributions of various parameters pertinent to the characteristics of structural systems. Accidential eccentricities due to horizontal propagating shear waves will also be investigated. The analytical results of this research will improve the basic understanding of the torsional effects in structures and thereby contribute to more consistent seismic design provisions in building codes.

FATIGUE TESTS IN FULL-SCALE BLOCK WALLS

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Sponsor: Bureau of Mines

The Bureau of Mines is responsible for providing information on the levels of blasting that could cause damage to surrounding construction during mining operations. Past history has revealed the need for defining first cracking capacity of block walls. This and other types of construction have been involved in a number of legal actions. The investigation will involve experimental testing. Full-scale tests have been conducted by the Bureau of Mines. They are seeking additional experimental data that only CBT has the facility to provide. The experimental program will include tests on planar wall specimens and corner specimens. Loading will include both load-rate effect and cyclic-loading effect. Although the Bureau of Mines requirement for information is limited to first cracking, the investigators plan to examine ultimate load capacity as well to fit this research into the overall CBT research program on masonry construction.

LARGE-SCALE BRIDGE COLUMNS SUBJECTED TO REVERSED CYCLIC LOADING

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Sponsor: National Science Foundation

A national workshop on earthquake resistance of highway bridges held in January 1979 identified research needs and established priorities in the area of seismic aspects of highway bridge design. One of the highest priority research needs was to determine the effects of scale factor on bridge column design to determine whether the behavior of small sections can be extrapolated to large cross sections and to examine the performance of selected full-scale details. These two needs can be interrelated.

Experimental programs on large-scale specimens are expensive and difficult to conduct; hence, the limited availability of data in the literature. The test program will examine full-scale performance data over a range of axial loads and column designs. Such a range is necessary to examine the effect of scale factor since such an effect will likely be dependent on the column mode of failure. The program plan will consider columns designed using state-of-the-art techniques. Specimens at full-scale, 1/3-scale, and 1/6-scale will be selected. Many of the tests will be full size to take advantage of the NBS facility to obtain "bench mark" data. The scale tests that are conducted are expected to identify problems of scale effect but may not completely answer them. If necessary, a complete examination of scale effect will be possible in future investigations using the full-scale tests to provide reference data.

CYCLIC LOADING OF MASONRY BUILDING COMPONENTS

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Sponsor: National Bureau of Standards

The process of developing tentative seismic design provisions for both unreinforced and reinforced masonry building components reveals a scarcity of information on ultimate strength characteristics. Since seismic resistance is now based primarily on ultimate strength considerations, the lack of such information for masonry is detrimental to rational design of buildings subjected to seismic loadings. Here, experimental tests will provide vitally needed information not now available that will serve as the basis for development of mathematical models. A number of failure modes will be examined to identify the characteristics of each and the significant parameters affecting the different failure modes.

Analytical expressions for predicting failure as a function of key parameters will be developed. Later experimental testing will determine the generality of the proposed analytical expressions. This research will provide engineers with a sound base not currently available by presenting experimentally verified rational approaches for ultimate strength design.

CONSTRUCTION ENGINEERING

Construction Load Effects
Structural Condition Assessment Standards
Sonic-Pulse-Echo Inspection of Concrete
Performance of Concrete Structures in the Arctic
Safety in Concrete Construction
Development of Safety-Net Standards for Construction

CONSTRUCTION LOAD EFFECTS

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Sponsor: National Bureau of Standards

Compared with the provisions for occupant protection, current codes and standards provide little or no coverage on the protection of buildings during construction. This is attributed to a lack of substantive information on construction loads and their effects on the partially completed structure and the temporary support system. At the present time, the Equivalent Frame Method prescribed by the ACI 318 Code allows the two-dimensional representation of space structures for analysis. However, when floors are interconnected by shores as in construction, analysis of the structure using an Equivalent Frame Method gives inaccurate results. To achieve a reliable level of safety in the design of concrete structures during construction, there is a need for the appropriate load factors to be used. Under this project, a valid analytical model for concrete buildings under construction will be formulated. The field data on construction loads obtained earlier will serve as a guide in the formulation of probabilistic models for construction-load effects.

This analytical basis for evaluating construction loads will lead to a reliable procedure for design of concrete structures under construction. A feasibility study of time-lapse photography in the evaluation of construction loads will lay out the groundwork for large scale and relatively economical construction load surveys.

STRUCTURAL CONDITION ASSESSMENT STANDARDS

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Sponsor: National Bureau of Standards

Throughout the U.S., increasing concern is being expressed for the need to more fully use the existing building stock. Expenditures for improvements to housing nearly matched those for new housing construction in 1981--$46.5 billion vs. $50 billion. The building rehabilitation process requires many technical decisions by designers, builders, and building officials relative to the condition of the existing building. But the data required to make these decisions are broadly dispersed and not readily accessible. It is necessary to subject such information to a consensus review and provide the design community with resource standards on building condition assessment for selected materials -- concrete, metals, masonry, wood, etc. In the end, this project will provide a more uniform approach to building rehabilitation and a more efficient use of the existing building stock.

SONIC-PULSE-ECHO INSPECTION OF CONCRETE

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Sponsor: National Bureau of Standards

The detection of voids, cracks, and delaminations in concrete is important in determining its condition in both new and old structures. Radiographic and ultrasonic methods can be used for inspecting the interior of a concrete member, but only if opposite surfaces are accessible. With the radiographic method, the concrete member must also be thin. A promising alternative is the sonic-pulse-echo method, in which only one surface needs to be available and thick concrete members can be inspected. Ultrasonic pulse echo is a standard method for detecting flaws in metals. Sonic-pulse-echo methods are based on a principle that sound waves propagating through a solid are reflected by discontinuities such as a crack or porosity, or by interfaces between phases of different densities or elastic moduli. Therefore, by analyzing the signal due to reflected waves it is hypothetically possible to determine the location of the heterogeneity of concrete, formation of shrinkage cracks, and normal porosity. Since even high-quality concrete can contain numerous discontinuities, results from tests made on concrete are difficult to interpret because of a lack of a fundamental understanding of the interactions of sound waves with discontinuities.

This project will form the basis for interpreting the results from pulse-echo inspection on structural building materials and components. This will encourage the use of NDE methods in inspecting new structures and those in service.

PERFORMANCE OF CONCRETE STRUCTURES IN THE ARCTIC

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Sponsor: Department of the Interior

Rising costs of fossil fuels have made it economically feasible to pursue new sources in arctic regions that were previously considered impractical due to environmental conditions. Large-scale concrete structures have been proposed and built, such as offshore drilling platforms, floating storage units, and land-based facilities. The arctic offshore environment poses serious problems for concrete structures and their durability. To enhance the productivity of structures in cold regions, there must be an understanding of the behavior of concrete in these environments. The primary thrust of this effort will be to document the state-of-the-art of construction methods and durability of concrete structures in cold regions. A comprehensive literature review will be performed including a survey of major groups involved in cold region construction. In addition, a workshop will be sponsored by CBT and the Canada Centre for Mineral and Energy Technology, which will bring together experts in the design and construction of concrete offshore structures to share past experiences and identify research needs. The proceedings of the workshop will be published.

SAFETY IN CONCRETE CONSTRUCTION

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Sponsor: Occupational Safety and Health Administration

In recent years there have been catastropic failures of concrete structures during construction, some causing human casualties and all causing construction delays. These incidents have been attributed to inadequacies in design or construction, and have underscored the need for maintaining a consistent safety margin against collapse through a better understanding of the nature and magnitude of imposed construction loads and their effect upon the partially mature concrete structure and the shoring system used in its erection. The goal is to develop a technical basis for the improvement of existing safety standards on concrete construction. This year's work will consist of the following tasks: reduction and analysis of construction load data obtained from the field, verification (and refinement, if necessary) of the analytical model against field data, and development of recommendations for the improvement of the OSHA standards for safety in concrete construction.

DEVELOPMENT OF SAFETY-NET STANDARDS FOR CONSTRUCTION

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Sponsor: Occupational Safety and Health Administration

Falls from elevated surfaces during construction are the principal source of worker casualties. Safety nets are used to impede falls in progress in many situations where active fall-protection devices, such as guardrails and safety belts, are either impractical, as in congested work areas, or are ineffective due to the absence of an adequate mechanism of support. Currently, there is no technical basis for the application and performance testing of safety nets used in construction. The purpose of this study is to develop comprehensive criteria for the use and testing of safety nets based on research results. This phase of the study will address the question of the adequacy of the minimum horizontal projections of perimeter nets that are currently widely used.

SERVICE-LIFE PREDICTION

Application of Life-Test Analysis Concepts to Building Materials
Cement Hydration
Performance of Concretes
Short-Term Evaluation Procedures of Coatings for Steel
Corrosion of Steel in Prestressed Concrete
Organic Coatings
Characterization of Blister Growth and Corrosion Under Protective Organic Coatings
Corrosion and Weathering Data
Corrosion of Alumininum Roofing
Evaluation of Single-Ply Roofing Systems
Performance of Bonded Seams in Single-Ply Roofing Membranes
Performance of Residential Siding
Tri-Services Technical and Scientific Support
Guide Specifications for High-Performance Latex Paints
Standards for High-Security Glazing Materials
Solar Collector Durability and Reliability Test Program
Standards for Solar Absorptive Coatings
Environmental Degradation of Polymeric Cover Materials for Solar Collectors
Evaluation of Optical Techniques for Measuring Absorber Materials Degradation
Degradation of Heat-Transfer Fluids in Solar Heating Systems
Documentation of Materials Research Data and Activities
Performance Criteria for Solar Systems in Commercial Buildings
Residential Solar Data Center
Solar Energy International Cooperation
Buffers for Glycol-Based Heat Transfer Fluids

APPLICATION OF LIFE-TEST ANALYSIS CONCEPTS TO BUILDING MATERIALS

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Sponsor: National Bureau of Standards

Reliable prediction of service life is needed to aid the selection and use of polymeric building materials. But major technical barriers to the development of predictive models arise from the complexity of the degradation processes, particularly the synergistic effects of ultraviolet radiation, temperature, moisture, and other factors. Currently, predictive models and accelerated tests do not account for this synergism. The thrust of this research is to develop stochastic models incorporating synergistic degradation effects. These models will be validated against laboratory and outdoor test data.

Prior research has led to the development of a stochastic model as a function of two of the above degradation factors (ultraviolet irradiance and temperature) using polymethylmethacrylate (PMMA) as a model material. This year the model will be extended to include moisture. PMMA specimens will be exposed to several relative humidity levels, keeping irradiance and temperatures constant. The level of moisture in each specimen will be measured using a Fourier transform infrared measurement technique. Degradation of the materials will be measured using gel permeation chromatography. In the mathematical modeling phase of the research, extensions will be made to the current stochastic model. Degradation will be modeled in terms of the chemical/physical changes occurring within the material.

The project will help put durability-related evaluation methodologies on a probabilistic basis, advance the technology of service-life prediction by providing an improved predictive model and by demonstrating an approach that can be used with a wide range of building materials, provide an improved understanding of the mechanisms of degradation, and identify paths of future research for other building materials and components.

CEMENT HYDRATION

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Sponsor: National Bureau of Standards

Portland and related cements are essential to the Nation's construction projects. Over $3 billion each year is spent on these materials, which are used in concrete construction costing about $20 billion. With the growing availability of computers, sophisticated analytical instrumentation, and laboratory automation, there are opportunities for improving our understanding of cement hydration so as to make possible more reliable predictions of concrete performance. Application of this knowledge will lead to improved standards for cements, greater uniformity of cements, improved cements, more effective use of material resources (including suitable wastes) in cement and concrete, and greater productivity in the cement and concrete industries.

The main product sought from this project is an established competence in cement science to provide a basis for significantly improved predictions of the performance of cements in concrete. This includes microstructural investigations, measurement of hydration rates, and aqueous phase analyses all leading to the development of mathematical models. Reports on the experimental results and the mathematical models obtained during the competence building are being published. The results of the research and its implications are being brought to the attention of the cement and concrete community through publications in the scientific and technical literature, through reports to technical committees in ASTM, ACI, TRB, and RILEM, and participation in Engineering Foundation Conferences on cement.

PERFORMANCE OF CONCRETES

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Sponsor: National Bureau of Standards

Improved understanding of the cracking mechanisms and the effects of environment on these mechanisms is needed for development of models for reliably predicting the performance of concrete. On a macroscopic level, there has been considerable research on the cracking of concrete and several attempts have been made to apply the fracture mechanics approach. It is now clear that the classical fracture mechanics approach, based on Griffith's theory of brittle fracture, does not give an accurate representation of cracking in concrete. A major obstacle in applying fracture mechanics is an inadequate representation of the cracking process.

The purpose of this project is to investigate the damage zone in concrete and develop analytical models describing the damage zone and cracking processes. For example, a damage zone that acts as an energy sink, appears to surround microcracks. However, the conventional fracture mechanics approach does not adequately handle this damage zone. Quantifying the effect of the damage zone on the cracking process and the strength of concrete will aid in the development of an improved understanding of concrete deterioration and a basis for more reliable service life predictions of concrete.

SHORT-TERM EVALUATION PROCEDURES OF COATINGS FOR STEEL

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Sponsor: Federal Highway Administration

Each year state transportation bureaus spend hundreds of millions of dollars protecting, from corrosive environments, bridges and other steel components associated with highways. To a large extent, the magnitude of this expenditure is affected by coating durability, for coating durability dictates maintenance policy. Essential to the optimization of maintenance schedules is an estimate of coating performance or service life obtained from short-term tests and extrapolated to expected environmental and operating conditions. Obtaining service life data before applying a coating is a difficult task. The difficulty arises from the large number of material and environmental stress variables.

Because of the enormous magnitude of research needed to fully satisfy these objectives for all coatings and all exposure environments, it is essential to narrow the focus of the initial research to include degradation caused by the combined effects of temperature and moisture for only a few coatings.

While degradation may result from multiple factors (temperature, moisture, ultraviolet radiation, cyclic exposure, salt, pollutants, etc.), temperature and moisture are of primary importance for most coatings. Development of tests to reliably predict degradation from these two factors will help meet the most immediate needs and will lay the foundation for subsequent research involving other degradation factors.

CORROSION OF STEEL IN PRESTRESSED CONCRETE

James R. Clifton
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Sponsor: Department of State

On the basis of a proposal submitted to the U.S./Spain Advisory Commission for Technology and Scientific Research on September 23, 1977, a cooperative investigation between the Laboratorio Central de Estructuras y Materiales, Centro des Estudios y Experimentacion de Obras Publicas y Urbanismo (Spain) and CBT began in September 1978. The subject of the research was "Factors Affecting the Corrosion of Steel in Prestressed Concrete Structures" and the work was planned to extend over the 5-year period, 1978-1983. Prestressed concrete is a form of reinforced concrete that makes highly efficient use of concrete and steel but puts particularly severe demands on these materials. The use of prestressed concrete for building and other construction such as bridges and pipelines is important in both the United States and Spain, and its use is expected to grow. Although the problems encountered with the performance and durability of prestressed concrete in the two countries appear to be different, there is a common basis of need for technical knowledge about the problems. The purposes of this project are to develop an improved understanding of the factors affecting the corrosion of prestressing steel in concrete, and to contribute to the formation of a technical basis for making service life predictions.

The results of this project will have a broad impact on prestressed concrete technology through their influence on concrete standards and codes. This project will also make a significant contribution to the bases for making service-life predictions for prestressed concrete structures.

ORGANIC COATINGS

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Sponsor: Tri-Services Committee

The annual cost associated with the use of organic coatings in the U.S. exceeds $8 billion, more than half of which stems from the use of protective coatings in buildings and structures. If effective criteria for the selection and use of protective coatings were available, as much as 25 percent of these expenditures could be saved. An essential element of selection and use criteria for protective coatings is service life. But currently available methods for predicting service life based upon short-term tests do not adequately meet the need for data to aid selection and use. The objective of this research is to develop improved test and evaluation methods for predicting the service life of protective coatings under in-service use conditions; these methods can be used as part of improved criteria for the selection and use of protective coatings.

In developing the technical bases for improved test methods, 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. The research on mathematical models and mechanical properties will aid in the development of improved service life prediction methods. Data on service life will lead to improved guidelines for the selection and use of organic coatings, which will help in the reduction of maintenance costs.

CHARACTERIZATION OF BLISTER GROWTH AND CORROSION UNDER PROTECTIVE ORGANIC COATINGS

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Sponsor: National Bureau of Standards

An important failure mechanism of protective coatings for steel is the formation and growth of blisters beneath the coatings. These blisters ultimately lead to cracking and delamination of the coating. The purpose of this research is to understand, characterize, and model blister growth so that improved predictions of service life can be made.

The research for this year will initially focus on ways to improve the precision and accuracy of data obtained by infrared thermography, one method used to detect and characterize blisters beneath coatings. These include image quantification, use of newer equipment with better spatial and temperature resolution, and investigation of alternative measurement conditions, e.g., changing temperature. Quantification and data handling will be developed so that it is compatible with existing thermographic equipment as well as most equipment now on the market.

Once the image quantification work is completed, research will be performed to study rates of blister formation, blister growth, and corrosion for selected pigments and vehicles as a function of such variables as pigment type, pigment concentration, pigment size distribution, and coatings thickness. For a selected coating, blister growth as a function of concentration of soluble substrate contaminates will be determined.

Work will also continue using a second characterization and detection method, optical microscopy, with emphasis on determining rates of cathodic delamination as a function of coating type, environment, etc. Results of the experimental work will be used for further development of the preliminary mathematical model that has been developed for predicting the formation and growth of blisters beneath protective coatings.

The research will help in understanding corrosion mechanisms through studies to validate the preliminary model and will then serve to improve the performance of protective coatings. Also, the infrared thermographic method will provide data to serve as a technical basis for more accurate and precise evaluation standards than the currently used visual standards.

CORROSION AND WEATHERING DATA

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Sponsor: National Parks Service

This project is part of the nation's response to the acid rain problem. It consists of two tasks. In the first, significant long-term atmospheric corrosion and weathering data for metals, masonry, and coatings taken at active exposure sites will be identified. This includes the identification of any weather and pollution data taken at the exposure sites or at nearby monitoring stations. The second task is aimed at developing relationships between the deterioration rates and the environmental conditions at the exposure sites. The NBS Statistical Engineering Division will collaborate in the data analysis. If adequate long-term weather and pollution data are not available at some sites, the feasibility of estimating them based on short-term weather data will be explored. Then, the significance of the relationships found between material deterioration rates and weather data will be determined. Finally, recommendations will be made on gaps where new rate data need to be produced. The results of this research will be used in making the FY 1985 assessment of the effects of acid precipitation on building materials.

CORROSION OF ALUMINUM ROOFING

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Sponsor: Defense Logistics Agency

Over 730,000 ft^2 of aluminum standing-seam roofing was applied over built-up roofing that failed prematurely at the Defense Construction Supply Center, Columbus, Ohio. The built-up roofing was applied only 7 to 8 years ago. The aluminum standing-seam roofing is considered experimental for this type of reroofing application because of the relatively low slope of the roofs. This research will involve the monitoring, testing, and evaluation of the performance of low-scope aluminum standing-seam roofing in an area exposed to severe "acid rain." Laboratory and field studies will be conducted to determine if corrosion is a problem. The evaluation of the performance will give information that will contribute to the formation of a basis for estimating the service life of the aluminum roofing. Available information regarding environmental conditions (Weather Bureau Data) to which the aluminum roofing is exposed will be obtained and recorded. Measurements will be made periodically of the pH of rain water collected at the site. In evaluating the performance of aluminum roofing, the environmental conditions will be considered. The results of this project will aid future decisions about the selection and use of aluminum for roofing, particularly in a corrosive environment.

EVALUATION OF SINGLE-PLY ROOFING SYSTEMS

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Sponsor: Tri-Services Committee

A recent survey projected that single-ply materials will account for 25 percent of low-sloped roofing by 1985. Furthermore, there are more than 100 products available and marketed as single-ply membranes in this country. Standards and criteria for single-ply roofing materials have not been established in the United States. The lack of standards, accelerated evaluative test methods, and performance criteria makes the selection and acceptance of single-ply systems difficult. The objective of this investigation is to prepare preliminary criteria for single-ply roofing systems based on an analysis of available information. This investigation will assist roofing research by providing information to be used as a basis for development of conceptual and mathematical models for roofs having sheet roofing membranes in order to determine minimum performance levels.

PERFORMANCE OF BONDED SEAMS IN SINGLE-PLY ROOFING MEMBRANES

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Sponsor: National Bureau of Standards

Since the mid-1970's, the use of single-ply membranes for low-sloped roofing systems has increased rapidly. These materials now account for more than 10 percent of the roofing membranes applied in low-sloped roof construction. A recent survey has projected that sheet membrane materials will account for 25 percent or more of low-sloped roofing in 1985. Installation costs in 1985 for this amount of sheet roofing will range from $1.8 to $3.6 billion, if the present installation costs of $3 to $6 per square foot are assumed.

Currently over 100 sheet roofing membrane products are being marketed and the number of products is increasing. The major types of membrane materials are synthetic rubbers, plastics, and modified bitumens. Many of these materials are reinforced with a glass or polyester fabric. Seam fabrication techniques vary depending upon the type of material. A major problem has been the failure of seams. In 1980, the National Roofing Contractors Association indicated that the most common problem reported by its members was the delamination of sheet seams.

Standardized test methods and performance criteria applicable to seams fabricated from the different types of sheet materials are not available to determine whether a seam will perform satisfactorily. In this project, test methods and performance criteria will be developed for evaluation of seam performance. This project will help to minimize premature failures of the $2 billion or more of sheet roofing membranes estimated to be put in place every year from about 1985 on.

PERFORMANCE OF RESIDENTIAL SIDING

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Sponsor: Tri-Services Committee

The increasing use of residential siding materials, both in new construction and maintenance, has led to the need for performance criteria to aid in the selection of materials. Of particular interest are criteria addressing durability performance. The Department of Defense previously supported CBT research to develop interim performance criteria for sidings. During its first year, laboratory tests were conducted on repainting the weathered siding materials. Adhesion tests using the field adhesion tester developed at CBT were carried out to determine the compatibility of the alkyd and latex coatings with the weathered substrates. The initial adhesion tests were conducted two months after repainting the siding materials. The repainted siding materials were then exposed to outdoor weathering. Adhesion tests using the field adhesion tester will be conducted on the repainted panels after 9 and 18 months' exposure. After 18 months' exposure of the repainted panels, data will be analyzed, existing criteria evaluated, and criteria will be prepared for recoating siding materials.

TRI-SERVICES TECHNICAL AND SCIENTIFIC SUPPORT

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Sponsor: Tri-Services Committee

This project will provide technical and scientific support and consultative services on building materials and systems as required by the Tri-Services. The work will include carrying out laboratory tests and field investigations for solving building problems. Recommendations will be made on the selection of materials and systems and their application and performance. In the past, problem areas have covered plumbing, masonry, roofing, corrosion, mechanical systems, insulation, materials, and underground piping.

GUIDE SPECIFICATIONS FOR HIGH-PERFORMANCE LATEX PAINTS

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Sponsor: Air Force Engineering and Services Center

Recent failures of both interior and exterior latex paints have been reported by a number of Air Force Bases. These failures include poor washability and scrubbability for interior paints and poor adhesion and durability for exterior paints. Evaluation of preliminary data on high-performance paints in the marketplace showed that their performance and durability may be better than that of paints currently being used on military bases. Additional experimental data are needed to provide the technical bases for improved specifications.

Under this project, performance requirements and essential attributes of high-performance latex paint systems will be identified. Studies will be conducted to identify the mechanisms by which currently used products are degrading and thereby falling short in the required levels of performance. Laboratory tests will be developed to assess paint systems to ensure that performance meets the designated levels. These tests will be used as the bases for new and improved criteria and specifications by the Air Force -- thereby extending paint lifetimes and lowering maintenance costs.

STANDARDS FOR HIGH-SECURITY GLAZING MATERIALS

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Sponsor: Law Enforcement Standards Laboratory

During this three-year project, the status and problems of glazing materials used in high-security applications will be determined, realistic threat levels will be established, and performance tests and criteria will be developed. Based on the information obtained in FY 1982, combined mechanical and thermal attack was determined as one of the likely threat scenarios. Thus, performance tests simulating combined mechanical and thermal attack will be developed. Also, methods will be developed to determine the impact characteristics (velocity, force, and loading rate) of manually operated impact tools, and will be used to calibrate mechanical impact devices used in the combined mechanical-thermal tests. Performance tests for other threat types including failure of the glazing as a unit and/or the window assembly are needed but they cannot be accomplished within the scope of this project. The major product will be a draft performance standard for glazing materials used in high security applications. Also it will be brought to the attention of ASTM Committee F12, which is concerned with security glazing, for possible incorporation into ASTM standards.

SOLAR 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 3 to 9 weeks. Various component and materials tests have been proposed to evaluate the reliability/durability of solar collectors. However, these testing procedures have to be experimentally validated. 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. So far, these procedures have been incorporated into the solar performance criteria and MPS documents that CBT has prepared for HUD and DoE. In addition, they are being submitted to ASTM and other concerned organizations for consideration as consensus standards and will be of value in the establishment of testing procedures for the certification of solar collectors.

STANDARDS FOR SOLAR ABSORPTIVE COATINGS

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Sponsor: Department of Energy

To maintain its efficiency, a solar heating system must retain its original performance properties over the expected lifetime of the system. Of prime importance to the system is the function of absorptive coatings in the absorption of solar energy. While numerous standard test methods have been developed for coatings in building construction, the performance requirements involved in solar heating/cooling systems are quite different. For example, temperatures on the absorptive surface may reach 475°F or greater, but standard test methods for coatings seldom involve temperatures as high as 212°F. Standard test methods that can be used to evaluate absorptive coatings under conditions of use are urgently needed. The purpose of this project is to prepare draft standards for absorptive coatings and predictive models to aid in interpreting data from the standards. The standards will be based upon the results of laboratory studies to evaluate available materials according to the performance required of them in service. The draft standards will be submitted to ASTM for consideration as consensus standards.

ENVIRONMENTAL DEGRADATION OF POLYMERIC COVER MATERIALS FOR SOLAR COLLECTORS

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Sponsor: Department of Energy

Virtually all of the durability testing that has been performed to date on polymeric materials has concentrated on their degradation when exposed to temperature and ultraviolet radiation. Little emphasis has been placed on degradation caused by moisture or by the combined effects of moisture, temperature, and solar radiation.

Under this project, moisture-related degradation that has occurred in cover materials exposed in previous CBT programs will be characterized. Carefully controlled exposure tests will be conducted for representative materials to determine their degradation mechanisms and degradation rates and a basis established for projecting the useful lives of these materials. Research will be performed to apply a stochastic mathematical model for predicting the synergistic degradation effects of moisture, ultraviolet radiation, and temperature. The model will also be validated for one or more additional materials to demonstrate its broad applicability.

Knowledge gained in this research will be of considerable value to industry in formulating polymeric materials for solar applications. The development of evaluation procedures, in cooperation with organizations such as ASTM, will also aid industry in the selection and use of polymeric materials. The development of validated mathematical models also will significantly advance the current state-of-the-art in predicting the rate of degradation of materials, which will, in turn, aid in providing evaluation tools for selecting and using such polymers.

EVALUATION OF OPTICAL TECHNIQUES FOR MEASURING ABSORBER MATERIALS DEGRADATION

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Sponsor: Department of Energy

Presently, integrated solar absorptance (per ASTM E424) and emittance (per ASTM E434) are the primary techniques used to measure changes in the optical performance of absorptive coatings by the solar industry. These methods have been incorporated into ASTM procedures concerned with the evaluation of absorptive solar receiver materials.

Studies conducted at CBT have shown that integrated solar absorptance measurements are a poor indicator of change in the optical properties of absorber materials. Such change typically occurs in the infrared region of the spectrum and is concealed by the integration process conducted as part of ASTM E424. ASTM E434 measurements are a more sensitive indicator of changes in the performance of selective absorber coatings; however, this technique provides no information about the spectral distribution of changes in optical performance of these materials.

Preliminary measurements made by CBT indicate that infrared spectral reflectance measurements offer considerable promise as a technique for the early detection of absorber materials degradation. Such techniques would be of considerable value to industry in the use of short-term exposure tests as a means for evaluating absorber materials.

The purpose of this research is to investigate the use of optical property measurements for the early detection of absorber materials degradation. The optical properties of typical absorptive solar receiver materials will be characterized by using techniques such as diffuse and specular infrared reflection spectroscopy, infrared emittance, and integrated solar absorptance. The sensitivity of these techniques to changes induced by short-term aging tests will be determined. The results of these studies will be published in an appropriate technical journal and presented to organizations concerned with the development of measurement techniques for absorber materials.

DEGRADATION OF HEAT-TRANSFER FLUIDS IN SOLAR HEATING SYSTEMS

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Sponsor: Department of Energy

One of the potentially major problems that may affect the durability of a significant number of solar collector systems relates to the lack of information on the rates of degradation of glycol-based antifreeze solutions. This is because the degradation of glycols generates acidic reaction products that cause accelerated collector system corrosion. Ethylene glycol and proplyene glycol may degrade by two major mechanisms under the conditions in a collector system. These are thermal decomposition and oxidative decomposition. Preliminary work at CBT has indicated that ethylene glycol is thermally more stable than propylene glycol but oxidatively less stable under one set of experimental conditions. It has also been observed that the presence of certain metals catalyzes the oxidative decomposition of glycols. Therefore, the degradation kinetics of these compounds will be investigated as functions of temperature, availability of O_2, availability of CO_2, and the presence of metals. Methods of analysis including mass spectroscopy and ion chromatography have been developed. This information will provide the basis for estimating the useful lives of glycol-based heat-transfer fluids used under normal operating conditions.

DOCUMENTATION OF MATERIALS RESEARCH DATA AND ACTIVITIES

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Sponsor: Department of Energy

Since 1975, ERDA and DoE have devoted considerable emphasis and resources to research and development activities pertaining to materials used in active solar heating and cooling systems. These activities need to be documented so that summary data and information (objectives, scope, results and conclusions, reports published) will be accessible to researchers, materials developers, and users. The information should be of considerable value and assistance to manufacturers and developers in their selection and use of newer materials for solar application. CBT, in cooperation with the other research facilities involved with materials research (i.e., SERI, NASA, LANL) will compile an annotated bibliography of research studies (1975-1981) related to active solar materials performance. The document will be organized by subject matter for ease of use. It is anticipated that a related effort will be undertaken by Los Alamos National Laboratory (LANL) for the compilation of data and information which has resulted from materials research at LANL and through materials R&D contracts monitored by LANL for DoE. The NBS and LANL efforts will be coordinated and will result in either a joint publication or compatible and coordinated separate publications. This project will aid manufacturers and developers in the selection and use of newer materials for solar applications.

PERFORMANCE CRITERIA FOR SOLAR SYSTEMS IN COMMERCIAL BUILDINGS

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Sponsor: Department of Energy

An interdisciplinary team, organized from CBT staff members and with the assistance of outside contractors, participated in the preparation of draft standards and performance criteria and is participating in the evaluation of demonstration system performance. Experience gained from the evaluation of system performance will be fed back into the development of improved criteria.

During FY 1981-1982, CBT staff assessed review comments resulting from a request for public comment in the Federal Register by HUD for the proposed document NBSIR 80-2095, "Performance Criteria for Solar Heating and Cooling Systems in Residential Buildings." Comments were also solicited directly from industry, professionals, standards organizations, as well as other Federal agencies. The response to these comments also will provide material for updating a document for commercial buildings.

RESIDENTIAL SOLAR DATA CENTER

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Sponsor: Department of Housing and Urban Development

In this program, raw data on commercialization and accelerated use of solar heating and cooling are collected, stored, processed, and transmitted to users and contractors for additional study, evaluation, and dissemination. In FY78, the transcription forms for getting raw data onto the computer were designed and put into use. The system for processing this data was then designed and documented. A prototype of the system was written and tested, the design was modified as needed, and computer programs and procedures were written to implement the system. Documentation was written and users of the system were trained. Since then, the program has been operational and has been drawn on by numerous researchers. The building community will continue to have access to this data through FRC or indirectly through technical reports published by CBT researchers and other HUD contractors. Indirect benefits come through standards and performance criteria developed by CBT and through technical reports from other project participants.

SOLAR ENERGY INTERNATIONAL COOPERATION

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Sponsor: Department of Energy

CBT has a major role in the U.S. development of test methods for determining the performance of solar energy components and systems for the heating and cooling of buildings. DoE has requested that this expertise be used to contribute to the international cooperative research in collector test methods organized by the International Energy Agency as part of its Solar Heating and Cooling Research Program. Specific objectives of the IEA collector test task include improving our ability to characterize the thermal performance of solar collectors, developing techniques for predicting the service life of solar collectors, and most recently, developing methods to demonstrate that installed solar water heaters are performing properly. CBT is contributing results from its own as well as other U.S. solar research efforts, and is facilitating the flow of technical information from abroad into the U.S. solar program. The near-term product will be a series of technical reports produced by the task participants. In the long term, international standards for solar collector testing and thermal performance evaluation of solar energy systems will be developed by ISO using U.S. and other national standards.

BUFFERS FOR GLYCOL-BASED HEAT TRANSFER FLUIDS

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Sponsor: Department of Energy

This project is intended to study a method for preventing an increase in the acidity of glycol-based antifreeze during system operation, and thus controlling a factor that contributes to accelerated corrosion. The technical approach is to determine the effectiveness of the addition of common ions to heated glycol-based heat-transfer fluids for maintaining the initial pH of the solutions. The pH values of 50-percent byvolume solutions of the glycol heat-transfer fluids are in the range of 8-9. The major acidic degradation products of ethylene glycol have been identified as oxalic, glycollic, and formic acids. Propylene glycol yields oxalic, lactic, formic, and acetic acids. These organic materials are weak acids and not totally dissociated in aqueous solution.

Soluble salts corresponding to the organic acids identified as degradation products from ethylene and proplyene glycol solutions will be added to the respective glycol-based heat-transfer liquids. These buffered solutions will be heated and their stability monitored to determine the effectiveness of the common ions added to suppress a decrease in solution pH. This will be carried out as functions of solution temperature, solution composition, and the presence of metals.

This research will provide the bases for recommendations, suitable for incorporation into standards, to protect solar components against corrosion.

QUALITY ASSURANCE

NDE of Building Materials
Security Barriers
Development of Tests for Predicting Adhesive Bond Durability
Laboratory Accreditation: Solar Collector Testing
AASHTO Materials Reference Laboratory (AMRL)
Cement and Concrete Reference Laboratory (CCRL)

NDE OF BUILDING MATERIALS

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Sponsor: National Bureau of Standards

This project is a study of the existing and proposed methods for nondestructive evaluation of in-place building components and materials. The techniques are useful not only in day-to-day construction but also in rehabilitation of older housing stocks and evaluation of buildings after natural disasters such as hurricanes or earthquakes. The results of this project are being brought to the attention of material scientists and material engineers through workshops, presentations at national meetings, and publications. Its purpose is to develop a technical basis to assist in the selection of appropriate NDE methods.

SECURITY BARRIERS

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Sponsor: Defense Nuclear Agency

Previous work at CBT has demonstrated that man-passage openings could be produced in security barriers in surprisingly short times using readily available portable equipment. The times have been short enough to require a reappraisal of the use of these barriers for specific physical security applications. These applications include storage of nuclear and conventional weapons, radioactive material, secret documents, and precious metals. Furthermore, it appears that the deterrent capabilities of many barriers currently accepted for security applications may provide little resistance to penetration by newly-developed attack equipment such as the rotohammer, ring saw, Jet-Ax, and burning bar.

Many of the existing security barriers were constructed over 20 years ago and some of them have deteriorated to an extent that they need to be repaired. In addition, retrofit measures are being considered to upgrade the penetration resistance of existing structures. It is necessary to determine the condition of the existing building materials to select the proper repair of retrofit method. The use of nondestructive evaluation methods for evaluating the condition of existing materials in security barriers will be explored in this project.

This work will assist the Defense Nuclear Agency, other government agencies, and private organizations. Further, it will contribute to understanding the performance of concrete subjected to impacts, explosions, earthquakes, and fires. Information from this study will also be applicable to projects on rehabilitation and safety of buildings, earthquake hazard reduction, and nondestructive evaluation.

DEVELOPMENT OF TESTS FOR PREDICTING ADHESIVE BOND DURABILITY

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Sponsor: U.S. Army

All branches of the military use lightweight, air transportable, rigid structures that serve as combination shipping containers and shelters for many types of tactical and life-support services. The use of these shelters has increased rapidly in recent years and life-cycle costs have become a major consideration. The shelters are fabricated from either paper honeycomb core or foam-plastic sandwich panels. While honeycomb panels have several potential advantages, field experience has shown many problems. Debonding of panel components, stemming from poor adhesive performance, is a frequently observed problem. To address poor adhesive performance, there is a need to develop improved accelerated tests and probabilistic models to aid in predicting service life.

This research will provide the technical bases for standards for adhesives used in honeycomb sandwich panels. These standards will contribute to the technical basis for the expansion of the military shelter program that is to take place in the 1980's under the newly formed Joint Committee on Tactical Shelters. The benefits will be improved performance of military shelters and spinoff benefits for civilian shelters.

LABORATORY ACCREDITATION: SOLAR COLLECTOR TESTING

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Sponsor: Department of Energy

This project will document the need for a solar collector laboratory accreditation program. This documentation will be based in discussions with solar collector manufacturers, collector testing laboratories, various agencies and research organizations working in solar energy, and state solar energy offices. The results of this work will be vital to further solar-collector testing and certification programs.

AASHTO MATERIALS REFERENCE LABORATORY (AMRL)

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Sponsor: American Association of State Highway and Transportation Officials

Under this project, with the support of AASHTO research associates working under CBT supervision, measurement services are provided to both public and private laboratories working on transportation studies. At present, attention is focused on the testing of soils and bituminous materials and the measurement of frictional properties of highways. Procedures used in performing conventional quality assurance tests are observed for conformance to applicable national standards. Related test apparatus is checked with inspection equipment calibrated by CBT personnel or by AMRL personnel using CBT calibrated devices. Deficiencies noted during inspections are brought to the attention of laboratory managers. In addition, proficiency test samples are distributed at regular intervals to obtain information on laboratory performance. Plans for FY 1983 envision the distribution of 125 pairs of asphalt reference samples three times during the year, 200 pairs of soil reference samples and 140 pairs of aggregate reference samples two times each during the year, and 90 pairs of bituminous concrete samples once during the year. Inspections of laboratories and proficiency testing provide information about problems with test methods; the AMRL staff participates in standards writing activities to bring these problems to the attention of outside groups. At the request of the AASHTO Subcommittee on Materials, an annual listing of comments on the AASHTO standards is forwarded for consideration by selected technical sections of the subcommittee. Coverage of apparatus and procedures used in the testing of cement and concrete is delegated to the Cement and Concrete Reference Laboratory.

CEMENT AND CONCRETE REFERENCE LABORATORY (CCRL)

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Sponsors: American Society of Testing and Materials, U.S. Army Corps of Engineers

Over $4 billion of hydraulic cements are produced in the United States each year. The value of the concrete construction in which these cements are used is estimated to be on the order of $20 billion. Because of the large amounts of money and critical construction materials involved, standardization of testing to enhance the reliability of quality assurance measurements is most important. The CCRL contributes to this standardization through on-site inspections of apparatus and procedures used in the testing of cements and concretes, the distribution of proficiency test samples, laboratory investigations of testing problems, and participation in the activities of standards development groups. This work is performed by ASTM Research Associates working under CBT supervision.

Plans for FY 1983 envision the distribution of 250 pairs of portland cement reference samples and 170 pairs of concrete reference samples twice in the year; and 150 pairs of blended cement reference samples and 100 pairs of masonry cement reference samples once in the year. Inspections of laboratories and proficiency testing provide considerable information about problems with test methods; the CCRL staff participates in standards writing activities to bring these problems to the attention of industry and regulatory groups.

CRITERIA AND STANDARDS

Standards Interface for Computer-Aided Structural Design
Representation and Analysis of Construction Standards and Specifications
Format for Model Building Codes
Documentation and Assessment of PBS Building Systems Program
Office Automation Impact on Interior Environments
Economic Methods for Building Standards
Development of a Solar Regulatory System

STANDARDS INTERFACE FOR COMPUTER-AIDED STRUCTURAL DESIGN

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Sponsor: National Bureau of Standards

Computer-aided design (CAD) is critical to the improvement of construction productivity. Computers have been used in a signficant way to aid engineering analysis for many years, and are now being used to aid in the production of project drawings. However, major technical problems still lie at the juncture between generic structural standards and project-specific design conditions. Indeed, most of the computational effort involved in automated structural design concerns the checking of design properties against constraints imposed by standards, building codes, specifications, and other criteria. Researchers refer to this checking function as constraint processing, and agree that the efficiency and quality of constraint processing in automated structural design can be enhanced by separating generic standards data from project descriptive data and by linking these through a constraint processor, or standards interface. In contrast, commercially available structural design software treats standards data as an integral part of proportioning and checking algorithms. An important shortcoming of this approach is that entire software packages may be rendered obsolete whenever standards-writing bodies alter the contents of standards databases. By separating these databases, software maintenance costs are expected to decrease significantly. In addition, standards-writing organizations will be encouraged to test the ramifications of changes they consider, by "swapping" standards data modules, and simulating the benefits and costs associated with each in relation to some standard building design.

CBT research on the standards interface for CAD suggests a model for design automation based on these objectives. However, an effective constraint processor and an appropriate structure for organizing project-descriptive structural design data remain to be developed. This project will eventually speed-up and optimize the design of buildings. It has the additional benefit that future CAD systems will be less costly to develop and maintain, and will enable designs to be compared for alternative versions of building standards.

REPRESENTATION AND ANALYSIS OF CONSTRUCTION STANDARDS AND SPECIFICATIONS

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CBT has sponsored with the Office of Product Safety Policy the development of Standards Analysis, Synthesis and Expression Software (SASE). The SASE is built upon the work of CBT researchers and others, and is a systematic method for the analysis of standards, codes, and specifications. Now available for use, SASE can support the analysis and formulation of a wide range of building regulatory documents.

The initial software product delivered to CBT contained the minimal user and technical documentation sufficient for use by experts, and contained no tutorial materials necessary to train standards analysts in applying the system. Under contract with Carnegie-Mellon University, Dr. S. J. Fenves has produced for CBT during FY82 and early FY83 a set of educational and training documents built around SASE. These materials provide the basis for a series of training seminars, and for the use of SASE by standards committee members and other professionals. Wide dissemination of the new user-oriented technical documents and training aids, and for the software package itself, is a high priority. An important forerunner of the kind of seminar envisioned is the international workshop by correspondence on the rational analysis, formulation, and expression of standards, begun by CBT during FY82, and endorsed by CIB and ISO. With the delivery during FY83 of course outlines and other training materials, it will be possible to plan training seminars specifically oriented toward the needs of standards-writing organizations.

Work this year will include modifications or adjustments to the software. Links to an available database management system also remain to the developed, thus permitting the installation of SASE on a computer at NBS.

In the end, the SASE will provide a rational and systematic approach to achieving standards that are clear, complete, and consistent. It also will provide a basis for CBT research on the application of design criteria in computer-aided design.

FORMAT FOR MODEL BUILDING CODES

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Sponsor: Federal Trade Commission

The three U.S. model codes exist in three formats. These differences tend to increase costs and risks for designers, builders, and manufacturers working in multiple code jurisdictions; increase regulatory barriers to the introduction of new technology; increase costs and risks of losses for building owners; make comparisons of technical requirements in the model codes extremely difficult; and provide barriers to reconciliation of differences in the model codes. In addition, imperfections in the format of each individual code make it difficult to find provisions applicable to specific technical situations. As a result, the user is often unsure if all provisions have been found, and whether relationships among the provisions have been interpreted correctly. Such imperfections tend to increase errors and costs in construction, and create costly barriers to the introduction of new and improved technologies.

As part of this project, Codes Community Committee (CCC), including persons knowledgeable in model code development and use, will be organized, with support from the Federal Trade Commission. The CCC's function is to develop a consensus recommendation for a uniform model code format. CBT will provide technical support for the project in: analyzing the qualities required of the format; providing information for defining the scope to be reflected in the model codes; providing alternative organizations from which the CCC may select one or more fitting the needs of model code users; and providing an index that will define the location of all attributes and entities covered by the scope of each of the three model codes.

Improved format for model building codes offers possibilites for improving the quality of building regulations, enhancing opportunities for the introduction of new building technology, and reducing building cost.

DOCUMENTATION AND ASSESSMENT OF PBS BUILDING SYSTEMS PROGRAM

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Sponsor: General Services Administration

This project will: assess how well the PBS Building Systems Program (PBS/BSP) objectives were met in six facilities built to the program's specifications, recommend for PBS implementation opportunities for improved building technology and building procurement practices, report on the advisability of implementing a prequalification approach to building procurement, and identify significant building technology and procurement issues whose resolution will require further research.

The PBS Office of Design and Construction reported, in a professional journal, that it was exceedingly difficult to evaluate virtually all existing and proposed Federal office buldings because, at the time they were designed, no description of what they were intended to accomplish had been prepared. In the absence of such a description, reported the Senate Committee on Environment and Public Works, it is impossible "to later compare results with inventories and learn what went right and what went wrong." The six buildings completed under the PBS/BSP are exceptions to the foregoing because documentation on the intended technical objectives was prepared in advance. The object of this project is to "compare results with intentions and learn what went right and what went wrong." This project will define the PBS Building Systems Program in terms sufficiently precise to permit subsequent CBT assessment by using physical field measurements. Measurements will be made at "systems" buildings selected from among the six actually built under the program.

OFFICE AUTOMATION IMPACT ON INTERIOR ENVIRONMENTS

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Sponsor: General Services Administration

The state-of-the-art of office automation (and plans for future developments) will be compiled by means of a literature search, interviews, and a conference. The data will be analyzed to identify environmental characteristics of offices required for the most effective use of automation, e.g., acoustics, lighting, thermal, etc. The goal is to identify the characteristics of the physical environment that should be considered in the design of automated offices -- those which are most likely to influence the performance of office workers.

Using this information, and a review of documents concerned with the development of design guidelines for buildings and interior spaces, an interim guideline for the environmental design of automated offices will be prepared. A sample of automated office tasks will be studied under field conditions to evaluate the relationship of a limited number of environmental factors with the performance of automated office tasks. The particular tasks and environmental factors to be studied will be determined jointly by GSA and CBT.

ECONOMIC METHODS FOR BUILDING STANDARDS

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Sponsor: National Bureau of Standards

The building community needs sophisticated, practical methods and guidelines for evaluating alternative building technologies in a consistent manner. The need for standardized, improved methods and guidelines to help the building community achieve affordable buildings that meet performance objectives stems in large part from the rising costs of building materials, the high costs of construction due to safety/environmental regulations, the alleged decline in construction productivity, and the uncertain costs of energy.

In this project, economic methods will be developed for application to building problems. A report will be prepared on how to calculate discounted payback and simple payback for building investments. This report will be used by the ASTM E06.81 Subcommittee on Building Economics in developing the fourth in a series of recommended standard practices for evaluating the economics of buildings and building components. Services will be provided to the ASTM E06.81 Subcommittee to transform techniques already published by CBT/CAM into three additional ASTM-recommended standard practices for measuring the cost effectiveness of buildings and building components. One is on the internal rate of return; a second is on life-cycle costing; and a third is on benefit/cost and savings-to-investment ratios. An important element in the work is integrating ASTM and CBT inputs so that the resulting standard is useful and consensus can be reached by ASTM.

Technical support will also be provided to the CIB W.55 Working Commission on Building Economics and the CIB W.67 Working Commission on Energy Conservation in the Built Environment. For W.55, contributions will be made in developing measurement methods in three areas: life-cycle costs, construction productivity, and impact of building regulations. Technical leadership will be provided the U.S. Committee of CIB Counterpart Working Commission W.55 in bringing CBT and ASTM work on building economics to the attention of CIB W.55 and CIB W.67.

DEVELOPMENT OF SOLAR REGULATORY SYSTEM

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Sponsor: Department of Energy

A viable building regulatory system must be developed to accelerate solar energy heating and cooling applications in housing and buildings and also to protect the consumer. This solar regulatory system must complement the existing regulatory system and provide a mechanism to accommodate the acceptance of a variety of solar systems, components, and modes of operation. In addition, a number of states and other jurisdictions are developing their own solar regulatory systems and a multitude of uncoordinated, nonuniform regulations may slow the development of an efficient solar industry. Successful completion of this program will discourage proliferation of these separate, nonuniform solar codes.

Model solar building regulatory provisions were developed under the sponsorship of the Council of American Building Officials (CABO) using the ANSI "accredited organization" approach and published by DoE in June 1980 as "Recommended Requirements to Code Officials on Solar Heating, Cooling and Hot Water Systems -- Model Document for Code Officials on Solar Heating and Cooling of Buildings." CBT, together with DoE and HUD, will provide oversight assessments regarding the progress of the program toward meeting its overall goals.

THERMAL INSULATION

Thermal Analysis and Modeling
Calibrated Hot-Box Measurements
Guarded Hot Plate and Heat-Flow Meter

THERMAL ANALYSIS AND MODELING

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Sponsor: National Bureau of Standards

Under this project, the techniques of finite-element and response-factor modeling will be used and developed in the analysis of the Calibrated Hot Box apparatus and composite walls. The modeling of "flanking" loss through the test-specimen holding frame and within complex walls is of highest priority. Error analyses on the 1-meter Guarded Hot Plate, Heat-Flow Meter, and Calibrated Hot Box will be done. Both analytical and finite element techniques will be used to model losses and edge effects. In addition, the parametrical dependence on the specimen thermal properties and physical dimensions will be determined by statistical analysis. The insulation manufacturers and testing community should welcome this improvement of the accuracy of their calibration standards, so that lower-cost insulation can result and fairness among manufacturers and between manufacturers and consumers will be enchanced.

CALIBRATED HOT-BOX MEASUREMENTS

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Sponsor: Department of Energy

In the development of performance standards and specifications, the need for better technical data and improved test methods for building materials and envelope systems is critical. This activity is a key element in the DoC/DoE National Program for Building Thermal Envelope Systems and Insulating Materials. This year, assembly of the box will be completed and tests for acceptance of the equipment from the contractor will be finished. Specimen walls constructed of materials selected for the ASTM C-16.30 Round Robin (4-inch thick expanded polysytrene insulation board) will be used for these tests. This project will help improve the technical base and test methods needed by industry to reduce energy requirements of the envelopes of new and existing buildings by 40 to 50 percent.

GUARDED HOT PLATE AND HEAT-FLOW METER

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Sponsor: National Bureau of Standards

This project will use the newly developed CBT line-source guarded hot-plate and heat flow meter apparatus to experimentally obtain quantitative data on the heat and mass transfer behavior of thermal insulation and building materials including the effects of moisture on thermal performance. The designers and manufacturers of products that constitute the building materials market will use the information to produce at lower cost with improved performance. An understanding and quantification of the phenomena occurring within materials such as convection and/or moisture will also allow designers to negate undesirable effects by designing around them. Further, research of this type acts as a catalyst for innovative change to produce new and more efficient materials and applications.

THERMAL PERFORMANCE

Field Measurements of Wall Thermal Mass
Multi-Room Thermal Modeling
Underground Heat Distribution Systems
Earth Contact Heat-Transfer Modeling
Heat Loss through Thermal Bridges
Energy Analysis For ASHRAE-90A Revision
Energy Analysis Procedures
Air Infiltration in Large Buildings
Diagnostic Procedures for Federal Building Envelopes
Thermographic Mapping of Down Spouts in Treasury Building
Transient Performance of Building Defects
Laboratory Tests for Thermographic Standards
Energy Performance of Residences
Thermal Test Methods--Solar Collectors
Thermal Test Methods--Passive Components
Solar Hot Water Test Program
Response of Radiometric Converters to Sky-Radiance Distributions
Response of Radiometric Converters to Extended, Close Sources

FIELD MEASUREMENTS OF WALL THERMAL MASS

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Sponsor: Department of Energy

Six 20-ft wide and 20-ft long, one-room test buildings have been constructed at the NBS Nike Site. All six test modules have the same floor plan, orientation, and other common features, but with differing wall constructions. During FY83, a one-week special-purpose test to measure the thermal time constants for the test buildings will be carried out. For this test, the heating plants for the buildings will be turned off, and the decay of indoor temperature will be monitored. The time constant is the time required for the indoor temperature to decay to within 63 percent of its final steady-state value. The time constant is equal to the ratio of the envelope heat-transfer coefficient to the active envelope heat-capacity coefficient. The purpose of the test is to permit the heat-capacity coefficients for the buildings to be determined and subsequently used to correlate the "thermal mass effect."

During the remainder of FY83, winter night temperature setback tests and additional summer night ventilation tests will be carried out using the four insulated test buildings. For the winter night tests, the thermostat set temperature will be set back ten degrees during an 8-hour night period. The effect of wall mass on the energy savings for night temperature setback will be evaluated. For the summer night ventilation tests, the test buildings will be naturally ventilated during cool night periods, and the cooling energy consumed by the test buildings during this mode of operation will be compared with that consumed for the constant temperature thermostating mode of operation and with that for the FY82 night ventilation mode when power ventilation was used as opposed to natural ventilation.

The experimental field data reported will provide a preliminary validation of calculation procedures for predicting the impact of wall thermal mass on residential heating and cooling requirements. When supplemented with validating tests of full-scale residences in selected climates, the results will enable HUD, ASHRAE, building designers, and materials trade associations to perform credible evaluations of the cost-effectiveness of various design and material strategies.

MULTI-ROOM THERMAL MODELING

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Sponsor: National Bureau of Standards

This project will develop a comprehensive modeling technique for predicting simultaneous transfer of air, moisture, and heat in and through multi-room buildings. Although numerous building thermal modeling techniques and computer programs exist throughout the United States, none of them can handle the following processes simultaneously: envelope heat transfer, envelope air leakage, envelope solar heat gain, room-to-room heat transfer, room-to-room air and moisture transfer, intra-room air movement, energy consumption by the heating/cooling equipment, indoor comfort, water-vapor condensation, and contaminent migration. Existing models are virtually single-room models and dynamic coupling between the heated/nonheated spaces and/or the cooled/noncooled spaces are ignored.

Under this project, then, a comprehensive computer program package similar to the NBS BSS 69 report on the NBSLD will be prepared. Also expected are several technical and scientific papers on room air convection and inter-room heat and mass transfer. By advancing the state-of-the-art of building energy analysis, this project will assist the energy conservation design of buildings. Especially improved will be design procedures for passive solar, indoor air pollution, and smoke control.

UNDERGROUND HEAT DISTRIBUTION SYSTEMS

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Sponsor: Department of Defense Tri-Services Committee

Many underground heat distribution systems in military installations are failing because of the corrosion of the conduit system that covers the thermal insulation around the carrier pipe. Since it is an extremely expensive proposition to replace the entire underground system, it is desirable to have an accurate and easy-to-use instrument that will detect only the segments of the system that have failed. A simple heat transfer theory exists to translate the ground temperature profile over the underground heat source if the thermal properties of the earth and depth of the earth cover are unknown. This project will develop a practical technique to measure the thermal conductivity and temperature of the soil. This measurement system will be connected to a microcomputer for data analysis. When tested and validated, this technique is expected to assist in the development of innovative underground heat systems and encourage wider usage of existing underground systems.

EARTH CONTACT HEAT-TRANSFER MODELING

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Sponsor: National Bureau of Standards

CBT is currently developing a Green's function approach to solving the slab-on-grade heat transfer problem. This method was able to prove that the slab-on-grade problem can be analyzed by a combination of two analytical solutions, one dealing with a steady potential flow solution between the heated plane segment and the surrounding earth; the second is the two-dimension perimeter zone solution dealing with the periodic temperature fluctuation developed by Delsante. The combination of these two solutions permit the frequency domain analysis of the slab-on-grade floor heat-transfer problem. This solution can be combined with the conduction-transfer function for the one-dimensional multilayer slab structure to complete the solution for the composite slab-on-grade floor system where the effective slab insulation can be studied. It is further proposed that this frequency-domain solution technique for the floor slab be extended to the basement wall/floor problem. The new algorithms developed under this research will be submitted to the AHSRAE Technical Committee on Load Calculations TC 4.1 and Energy Calculations TC 4.7 for their adaptation to proposed procedures for building heat transfer analysis.

HEAT LOSS THROUGH THERMAL BRIDGES

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Building Physics Division

Sponsor: Department of Energy

Infrared thermographic inspection of the exterior and interior of a building envelope can reveal the locations and extent of thermal bridges in most classes of structure. However, thermography is not capable of quantifying the heat loss from such thermal bridges. This project will classify the types of thermal bridges occurring in typical commercial structures. Two-dimensional and three-dimensional heat flow models for each class of thermal bridge will be used to determine the location at which temperature and heat flow probes must be placed on the structure to measure the heat losses due to the thermal bridges and also to determine the minimum duration of measurements which will allow a reasonable estimate of the annual heat loss from the thermal bridge. A thermal bridge in an existing building will be monitored using the developed technique to assess the accuracy of the method. The results of this study can be used to decide whether it is economically sensible to fix a thermal bridge and to determine the long-term energy costs of thermal bridges about to be incorporated in new buildings.

ENERGY ANALYSIS FOR ASHRAE 90A REVISION

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Sponsor: Department of Energy

In this project, CBT will conduct a comprehensive set of annual energy consumption analyses for ten different commercial buildings under five different climatic conditions with respect to seven different designs: 1) ASHRAE 90-75 design, 2) ASHRAE 90A-80 design, 3) ASHRAE 90A-80 design with new chapter on systems and equipment, 4) ASHRAE 90A-80 with upgraded lighting criteria, 5) ASHRAE 90A-80 with upgraded envelope criteria, 6) ASHRAE 90A-80 with all upgraded criteria, and 7) same as (6) with daylighting application. These energy analyses will be conducted using the hourly simulation computer program DOE-2.1B.

ENERGY ANALYSIS PROCEDURES

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Sponsor: Department of Energy

The success of the Building Energy Performance Standard hinges on the availability of accurate, yet easy-to-use energy analysis procedures. Although DoE has identified the DoE-2 program as the standard benchmark energy analysis procedure, this program is often cumbersome for use by practicing engineers and energy officials because it is complex and requires large computers. To make effective use of DoE's BEPS, it is necessary to have manual energy-analysis procedures, which CBT was asked to develop and validate. A step-by-step procedure suitable for microcomputers was developed for performing simplified energy analysis for commercial and residential buildings.

CBT also developed simplified and comprehensive slab-on-grade and basement heat-loss calculation procedures for use in the hourly energy calculations. The algorithms will be tested on NBSLD before application to the DoE-2.1B computer program.

AIR INFILTRATION IN LARGE BUILDINGS

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Sponsor: Department of Energy

Compared with single-family dwellings, there is very little experimental data on the air-exchange behavior of large buildings. This is one of the crucial parameters in modeling energy usage, because heat transfer due to uncontrolled air leakage effectively bypasses insulation provided in the building envelope. In some buildings, more than one-third of the building thermal load is due to air leakage. Under this project, instrumentation for measuring the air exchange rate in the Collins Building in Glasgow, Scotland, and for the Park Plaza Building in New Jersey has been installed. These systems monitor the air exchange rate, the operation of HVAC and exhaust system fans, interior and exterior environmental parameters, and the surface pressure distribution across the envelope of the building. The FY83 effort will consist of gathering detailed air infiltration rates in eight additional buildings. CBT automated air infiltration equipment will be installed for one or two weeks in each of the major climatic seasons for these buildings. Better knowledge of infiltration rates and air leakage characteristics of large buildings will provide much needed information for modeling of buildings. Better modeling will lead to energy savings through improved construction to reduce unwanted infiltration, better accounting of irreducible infiltration for use in lieu of part of the mechanical ventilation load, and an economically effective design through balanced consideration of insulation and infiltration.

DIAGNOSTIC PROCEDURES FOR FEDERAL BUILDING ENVELOPES

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Sponsor: General Services Administration

This project will recommend diagnostic inspection procedures, measurement techniques, and intepretation methods for use in assessing the thermal integrity of Federal buildings. The product of this effort will be an interim technical report describing diagnostic procedures for Federal buildings and eight case histories of defects found in field tests. Practical and timely methods of pinpointing specific corrective actions will not only reduce the cost of eliminating energy-wasteful deficiencies, but will provide GSA with information feedback of great value in improving construction and retrofit practices.

THERMOGRAPHIC MAPPING OF DOWN SPOUTS IN TREASURY BUILDING

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Sponsor: General Services Administration

Many old historical buildings have roof drainage systems whose locations are unknown. These drainage systems often leak and cause damage to the building. A non-destructive method is needed for locating these drainage systems so that repairs can be made.

CBT will use thermographic methods to produce a map of the down spouts and roof draining system in the treasury building. The down spouts will be mapped by blowing hot air into the roof drains on a section of the building. CBT will perform a thermographic survey of the building from the exterior to determine where the down spouts are and translate this information to architectural drawings. If parts of the drainage system are not observable by exterior thermographic scanning, interior scanning will be performed. Two representative sections of the roof drainage system will be removed for NBS chemical analysis to determine the deterioration of the materials.

TRANSIENT PERFORMANCE OF BUILDING DEFECTS

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Sponsor: STRS

Theoretical models of transient performance of building defects will be developed to aid in quantitative interpretation of thermographic data. Included are surface models for each class of defect in the thermal envelope (voids, cracks, corners, thermal by-passes, moisture under solar loading, etc.) typically observed during the thermographic inspection of buildings. The models will be used with image processing equipment to generate theoretical thermograms of these defects under various transient conditions. Transfer functions representing the physical performance characteristics of the various types of thermographic equipment will be used with the theoretical thermograms to assess the ability of the equipment to observe and quantify the heat loss caused by a defect under transient conditions.

Thermography has proven useful for qualitative assessment of the building envelope. The extraction of quantitative data from thermographic surveys requires a more detailed analysis of the physical processes in buildings which produce the thermal patterns observed during thermographic inspections. A series of guidelines will be developed for quantitative assessment of data obtained from thermographic inspections of buildings. In FY83 the theoretical basis for such guidelines will be established. The guidelines from this project will be used by ASTM and ISO subcommittees in developing standards for the thermographic inspection of building envelopes.

LABORATORY TESTS FOR THERMOGRAPHIC STANDARDS

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Sponsor: Department of Energy

In this project, ground-based infrared imaging systems and inspection techniques will be evaluated for their application to building heat loss detection. The adequacy of various standards for thermographic inspections such as the ASHRAE standard, the draft ASTM standard, and the ISO standard will be assessed. CBT will perform the laboratory test procedures suggested in these standards. The evaluation of the equipment specifications for spatial resolution, thermal resolution, noise characteristics, geometrical response, signal transfer function, and summary measures will be carried out in the laboratory on candidate infrared sensors used for building inspections. The laboratory evaluations will be performed in CBT environmental chambers to assess the effect of both object temperature and ambient temperature on the equipment parameters. The results of these laboratory tests will be correlated with observed building defects to determine the importance of each equipment parameter on the conditions under which the equipment is used for heat loss detection. This project will lead to guidelines for assessing the benefits of thermographic inspections of buildings and the relative advantages of various classes of thermographic equipment.

ENERGY PERFORMANCE OF RESIDENCES

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Sponsor: Department of Energy

This project will use the data obtained from more than 100 houses in the CSA Optimal Weatherization Demonstration project to assess various combinations of simplified test methods that could be used to predict the whole-house performance of the dwelling and to signal changes in the energy performance. The techniques which will be assessed are: air infiltration rate measurements by both the pressurization method and the tracer gas method, electric co-heating, infrared inspections of the building envelope, methods for measuring the seasonal efficiency of the building heating and cooling systems, and methods for data handling, analysis and prediction of the energy losses due to the defects detected. The assessments resulting from this project will be presented at various meetings of building and utility trade associations and professional societies such as ASHRAE and ASTM.

THERMAL TEST METHODS--SOLAR COLLECTORS

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Sponsor: Department of Energy

It is critical to establish the conditions required to maintain comparability in solar simulator testing, and to determine what measurements must be made to understand the differences that do occur, before solar simulator testing becomes too well entrenched. There are already three commercial solar simulator test facilities in the United States, a large Federal facility in Canada, and there are or soon will be as many a thirty in Europe. Under this project, the solar simulator facility built for DoE at Marshall Space Flight Center is being recreated at NBS. Short engineering research studies will be conducted with representative generic collectors including flat plate and evacuated tubular types to characterize the effects of spectral quality, collimation, nonbeam radiation, and effective sky temperature. Other solar simulator facilities will be used as appropriate.

THERMAL TEST METHODS--PASSIVE COMPONENTS

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Sponsor: Department of Energy

Surveys to identify commercially available passive solar products based on advertising in solar product directories and review of papers presented at technical conferences and symposia will be continued to identify new products being marketed. Thermal performance test procedures and test data for these products will be reviewed, when available, and compared for generic groupings of these products to establish a common basis for thermal performance testing. Potential users of these products will be surveyed to determine the thermal performance test data and required reporting format.

Passive solar components have been classified into generic groupings according to their fundamental roles and a proposed thermal test procedure will be developed for each grouping. Analytical computer models will be developed for each grouping and representative components will be purchased. Thermal performance testing under both laboratory conditions at other facilities and under field conditions at the NBS Passive Solar Calorimeter Facility will be performed. The test data combined with the thermal modeling will be used to assess the ability of the proposed test procedures to provide appropriate thermal performance data.

SOLAR HOT WATER TEST PROGRAM

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Sponsor: Department of Energy

Experimental investigations are being carried out to test the thermal performance of innovative water-heating systems. Electric strip heaters attached to the absorber plates will be used to simulate the solar input. At least one system will also be tested in a solar simulator. These experiments will establish the testing procedure required for these systems and provide detailed system performance data required to validate performance models. To complete this research, the test methods and evaluation procedures must be extended to include systems where circulation is driven by solar input such as thermosyphon and refrigerant-charged water heaters.

RESPONSE OF RADIOMETRIC CONVERTERS TO SKY-RADIANCE DISTRIBUTIONS

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Sponsor: National Bureau of Standards

Existing test and evaluation procedures for building thermal equipment using solar radiation assume either that there is no diffuse sky radiation or that the diffuse sky radiation present is isotropic. Neither assumption is correct. A sizeable portion of the prevailing uncertainty in equipment testing can be attributed to the fact that the diffuse sky radiance is non-isotropic. The problem is particularly severe in testing innovative equipment that responds to nonisotropic radiation in ways different from the instruments used to measure the radiation. Since the equipment and the instruments are just different kinds of radiometric converters, some with electrical outputs, some with thermal outputs, the generic problem is one of characterizing the response of radiometric converters to sky radiance distributions.

Completion of this work will remove a major roadblock in the development of realistic rating procedures. It will provide the model for simulating long-term performance for the purpose of evaluation and rating. Working from the rating requirements, it will establish required modifications to current standard test methods.

RESPONSE OF RADIOMETRIC CONVERTERS TO EXTENDED, CLOSE SOURCES

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Sponsor: National Bureau of Standards

Testing and evaluating building thermal equipment in environmental simulation chambers is common practice. These chambers establish controlled conditions of temperature, humidity, and air flow appropriate for a test. Better test results can be obtained in less time in these controlled, stable, conditions. Recently, some laboratories have added another dimension to the controlled environment by installing large-area lamp arrays that simulate solar radiation. It is relatively easy to reproduce typical outdoor levels of irradiance using these arrays. However, the equipment under test and even the instruments used to measure the optical and thermal radiation often behave differently in these environmental/solar simulation chambers than they do outdoors because the lamp arrays are extended, close sources. Test methods and evaluation procedures must be developed that properly account for these differences. The instruments and equipment are just different kinds of radiometric converters, some with electrical outputs, some with thermal. Thus, the problem is one of characterizing the optical and thermal interaction of radiometric converters with extended, close sources.

This work will establish the technical basis for developing test methods and evaluation procedures for appropriate testing in environmental/solar simulation chambers. The immediate impact will be on the standards organizations developing such procedures for building thermal equipment.

BUILDING ACOUSTICS AND LIGHTING TECHNOLOGY

Acoustic Measurements for Buildings
Prevention of Traffic-Noise Problems
Visual Criteria
Task-Lighting Criteria
Illumination System Measurements
Optimized Model for Brightness
New Definition of Photometry
High-Efficiency Lights and Chromatic Response
Opponent-Color Approach to Color Appearance
Daylighting Studies
CEL-1 Lighting Program
The Use of Hazard Pictorials/Symbols in Mines
Hazard Pictorial Signage for Sand and Gravel and Crushed Stone Mines

ACOUSTIC MEASUREMENTS FOR BUILDINGS

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Sponsor: National Bureau of Standards

The acoustical properties of building materials, spaces, and systems and the acoustic power emitted by sources are currently inferred from far-field measurements of sound pressure levels using diffuse sound field theory -- a theory inappropriate for most situations. As a result, laboratory and field data are inaccurate and predictions of in-situ performance from laboratory data unreliable. A recent ASTM round robin showed that absorption coefficients of specimens tested in 16 laboratories vary by as much as 14 to 90 percent depending on frequency. Sound insulation data on nominally identical structures varied by a factor of 3 to 10. Transmitted sound energy measured in the field was 10 to 100 times greater than predicted. Unreliable data bases and test methods and reliance on diffuse sound field theory can result in costly overdesign or corrections after the fact. An error by a factor of 2 in sound insulation can result in a panel specification that is 90 percent more massive than required and costs 60 percent more.

Poor measurement and prediction technology in building acoustics is becoming a significant problem to the building industry since the number of cities having enacted laws containing quantitative acoustic requirements jumped from 50 in 1971 to 500 in 1980 and the number of building codes incorporating acoustic specifications jumped during the same period from 10 to 100. As more architects and developers are held responsible for meeting acoustic specifications, the need for accurate test methods, data bases and reliable predictions are sharply increasing. The results of this study may reduce measurement uncertainties by a factor of 2. Further, work on the properties of sound absorptive materials may reduce reliance on expensive acoustical absorbers while at the same time opening the market to new inexpensive or innovative materials.

PREVENTION OF TRAFFIC NOISE PROBLEMS

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Sponsor: Federal Highway Administration

The purpose of this project is to provide local government staffs with a simple method and a handbook, based upon available technology, including individual steps required to plan land use and building construction compatible with expected noise. The proposed handbook would integrate transportation noise prediction, site noise exposure, building envelope noise isolation, and building occupants' noise exposure. The document will provide a step-by-step description of the design process indicating how local data are incorporated into the evaluation of the building envelope noise isolation and the technical feasibility of achieving an acceptable environment through land use planning and control. Numerous examples will be presented to illustrate the use of the methodology. The text will be written in a "how-to-do-it" format using examples and graphics to illustrate the concepts embodied in the method developed. Technical details will be presented in a series of appendices.

VISUAL CRITERIA

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Sponsor: National Bureau of Standards

This project will develop a methodological basis and supporting data for standardizing lighting criteria for buildings. Laboratory research at CBT indicates that when visual sensitivity is measured by conspicuity of details (suprathreshold), the function relating luminance with contrast is different from that obtained when the visual task is threshold detection. An apparatus to assess conspicuities of office tasks relative to a reference five-bar target at suprathreshold levels has been constructed, tested, and calibrated. By direct comparison methods, the relative difficulty of two-dimensional office tasks will be assessed by varying the contrast of the five-bar reference task for equality in conspicuity. This project will contribute standardizing procedures, an apparatus, and a data base for evaluating visibility that is applicable to real-world interior lighting.

TASK LIGHTING CRITERIA

Gary T. Yonemura
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Sponsor: Lawrence Berkeley Laboratories

Laboratory research at CBT indicates that when visual sensitivity is measured by conspicuity of details, the function is different from that obtained when the visual task is threshold detection or suprathreshold contrast sensitivity. A visibility meter (conspicuity apparatus) was designed and built at CBT. Using this apparatus, the legibility of typical office tasks, as encountered in the real world (suprathreshold), will be assessed to a reference five-bar reference task. The simultaneous effect of the many task variables (e.g., contrast, color, size, blur, gloss, form and conspicuity) will be assessed to obtain the relative visual difficulty of various office tasks. These research findings are being presented to the Illuminating Engineering Research Institute (IERI) Energy Management Committee and the Recommendation of Quality and Quantity of Light Committee of the Illuminating Engineering Society of North America (IESNA) and in articles in the United States and European lighting journals.

ILLUMINATION SYSTEM MEASUREMENTS

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Sponsor: National Bureau of Standards

Building illumination practice has historically relied upon simplistic measurements of illumination levels, poorly defined reflectance values, and complex calculation schemes based upon inadequate data. New requirements for more cost-effective, energy conserving illumination systems are creating a demand for more precise, valid physical measurement techniques to guide systems design, evaluate the effectiveness of prototype and installed lighting systems, and contribute to the physical basis of vision research.

This year the performance of several potential near-field photometry methods will be evaluated in the laboratory for accuracy in measuring luminance distribution for office-sized workspaces. Methods for reflecting determinations of room enclosure materials will be investigated to contribute to second-generation design computations. The most promising method will be developed and more fully evaluated next year. The development and acceptance of these physical measurement methods will significantly contribute to the provision of more economical and productive lighting systems in buildings.

OPTIMIZED MODEL FOR BRIGHTNESS

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Building Physics Division

Sponsor: National Bureau of Standards

This project will contribute to a redefinition of photometry by developing a new formula that more accurately predicts the perception of brightness. Experiments have shown, for example, that when a very saturated red light is matched in brightness to a white light, the luminance of the white light is twice--or, in another experiment, four times--that of the red light, for the average observer.

The output of this research, the new formula for brightness, will be offered to the vision/lighting community for adoption. Its impact could be great: following a redefinition of photometry, DoE will presumably rewrite the regulations governing maximum permissible lighting levels in various types of buildings in terms of the new measure of amount of light. The CIE and IES will presumably also redefine the energy efficiency (luminous efficacy) of lamps in terms of the new definition of light output.

NEW DEFINITION OF PHOTOMETRY

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Sponsor: Department of Energy

This project will contribute to a redefinition of photometry by developing new formulas that agree more accurately with perceptions of brightness. Several multi-channel brightness models have already been published by vision scientists. In addition, a number of experiments yielding brightness-matching data for various viewing conditions are in the literature, although no such data set is considered definitive. A full-scale effort in this area will require the collection of extensive visual data, radiometric measurements, and computer modeling. CBT is already working in this area, with a project called "Optimized Model for Brightness." That project involves optimizing a generalized linear model of brightness so as to agree as well as possible with the most extensive single body of brightness-matching data currently available (a study done at the National Research Council of Canada). This project is a desirable extension of that effort. In this work, an existing nonlinear model will be generalized and optimized to best fit the same body of data. Since the nonlinear model is more elaborate than the linear one, the expectation is that a significantly better fit will result.

The development of a generally accepted redefinition of photometry would provide the basis for possible redefinition of the candela, an SI unit, the revision of IES Handbook and standards used by illumination system designers; the redefinition by CIE and IES of the light output and the energy efficiency (luminous efficacy) of lamps; and upgrading of performance standards for energy efficient building illumination systems (e.g., ASHRAE/IES Standard 90A) for reference by building designers, state and local building code officials, and agencies concerned with construction and operation of Federal buildings.

HIGH-EFFICIENCY LIGHTS AND CHROMATIC RESPONSE

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Sponsor: National Bureau of Standards

Many high-efficiency light sources are known to alter color appearance. The magnitude and duration of the distortion have not been determined. Pilot research at CBT has suggested that color sensitivity may be altered (chromatic adaptation occurs) significantly for up to 0.4 hours. Such shifts alter the appearance of colors even after exposure to the illuminant has ceased thus reducing ability to make accurate color judgments. Data on the extent of sensitivity shifts and changes in color appearance are required for making decisions about the types of lighting to be used in a building. Where transitions between different colored illuminants are experienced, for example, the effect on color appearance is greatly increased.

In this study, laboratory experiments assessing the magnitude and duration of shifts in the color sensitivity function following adaptation to a variety of illuminants will be conducted. Later, a series of experiments will be conducted to quantify the effects of the illuminants upon color appearance. These experiments will provide basic information on the effects of specialized illuminants upon color response in terms of changes in visual sensitivity and in color appearance. The results of all this will provide useful, quantitative data to the lighting practitioner. The results will also be used in guidelines for the use of colors and various high-efficiency light sources.

OPPONENT-COLOR APPROACH TO COLOR APPEARANCE

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Sponsor: National Bureau of Standards

There are only three types of color receptors in the eye, and their spectral sensitivities are broad and smooth. Also, colored objects generally have smooth reflectance spectra. It follows that certain broad features of an illuminant's spectrum should be more important than the fine details. Luminance and chromaticity are "broad features" routinely computed for lights. The goal of this project is to define a larger set of color-rendering features that may be calculated from simple formulas like those for chromaticity. A logical way to do this is by the method of generalized Fourier analysis. Within the framework of this mathematical method, enough freedom remains that the definitions can have data regarding the eye, natural lighting, and even common object colors worked into them. This will make the results more useful without complicating the calculations. In fact, it is the effort to work in data from the literature that will take up most of the time. Data regarding color vision will appear within the method as opponent-color sensitivity functions.

This project will show how to compute the main effects on object color of a change in lamps, and will make more clear why color rendering is important. It will provide explicit guidance to designers of building illumination systems.

DAYLIGHTING STUDIES

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Sponsor: National Bureau of Standards, Tri-Service, and Naval Civil Engineering Laboratory

The type, size, and configuration of window openings have a strong impact on building lighting, heating, and cooling loads. Daylight has been shown to have good potential for reducing lighting energy requirements; however, the effect of daylighting schemes on building heating and cooling energy requirements must also be considered. Since the luminous efficacy of solar radiation is typically two to three times that of electric light sources, the substitution of the proper levels of daylight for electric lighting can reduce heating and cooling loads substantially, while providing psychological and aesthetic benefits.

This year work will begin on collecting daylight availability data for vertical surfaces under partially cloudy sky conditions; data which are virtually non-existent and badly needed. Researchers also will validate the prediction routines against measured data for a variety of fenestration systems. Other work will improve the capabilities of prediction routines to enable evaluation of innovative fenestration designs and complex building configurations, such as are typically found with passive solar designs. Eventually, this project will produce a computer simulation program on daylighting/skylighting and technical reports with recommendations for energy-efficient daylighting practices, fenestration designs, and skylight use.

CEL-1 LIGHTING PROGRAM

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Sponsor: Naval Civil Engineering Laboratory

The Conservation of Electric Lighting computer program (CEL-1) was developed as a tool to assist the building designer in determining energy-efficient fenestration and lighting configurations. However, at its present state of development only the lighting energy, daylight illumination, and visual performance aspects of fenestration use can be evaluated. In addition, calculations can only be made for a single point in time (static analysis) as opposed to the annual dynamic analysis required to determine the impact of fenestration systems on net building energy requirements for the entire year.

In contrast, the BLAST program can be used to perform building energy and system loads analyses on an annual basis using hourly increments. However, the BLAST program does not consider the impact of daylighting, so it does not allow for complete evaluation of the effect of different fenestration systems on building thermal and lighting loads and energy. This project will result in a computer simulation program incorporating a hybrid version of CEL-1 and BLAST to enable complete evaluation of fenestration systems on building energy and loads.

THE USE OF HAZARD PICTORIALS/SYMBOLS IN MINES

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Sponsor: U.S. Bureau of Mines

In the first phase of this project, current practice in safety symbol signage in mines will be documented and analyzed. This includes collection and review of existing symbols and sign systems, as well as compilation of all applicable standards. In addition, the need for safety symbols shall be documented and categorized through visits to mines and mills, a mine-hazard analysis, review of pertinent research literature, and discussions with mine experts. Existing practices, symbology, and standards will be reviewed and compared to determine gaps and needs. Later, both laboratory and field-based research methods will be developed and applied with the goal of determining the characteristics of effective symbols under normal and reduced visibility. A set of mine safety symbol signs will also be evaluated by a selected sample of users at the Lake Lynn Experimental Mine Site and at another mine. A handbook of recommendations will be prepared as a chapter in the final report.

Documentation and detailed analysis of the results from this research program will provide the needed experimental base for hazard warnings in mining environments. Furthermore, because the principal investigator chairs the ANSI Z535.3 Subcommittee on Safety Symbols, CBT and BOM are in a position to transmit the research results to the standards community and prompt more effective hazard warnings.

HAZARD PICTORIAL SIGNAGE FOR SAND AND GRAVEL AND CRUSHED STONE MINES

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Sponsor: Bureau of Mines

Symbols used to provide emergency and safety information in building and mining/milling environments must communicate effectively under a wide range of visual conditions which can include poor illumination, dust, and glare. These symbols and pictorials must be legible, conspicuous, and understandable to all those who encounter them, even over a period of time. There is little agreement on the characteristics of symbol signs which contribute to legibility and conspicuity, as well as understandability.

This research will focus on studying the overall effectiveness of safety symbols under in-mine conditions including poor legibility. During the in-mine evaluation, physical variables such as contrast, luminance, and general degradation will be assessed for a set of hazard pictorials at two aggregate mines. (These mines typically have problems with dust, thus affording an opportunity to study legibility problems first hand.) In addition, the conspicuity and understandability of the symbols will be assessed with mine personnel following installation of the signs. A report summarizing the analysis of symbol effectiveness in in-mine applications will be prepared. It will document the conspicuity and understandability data as well as the physical measurement data for the set of installed hazard pictorials.

BUILDING THERMAL EQUIPMENT

Evaluating the Performance of Heat Pumps
Heat Pump and Air Conditioner Test Procedures
Examination of Non-Azeotropic Mixture Refrigerants for Heat Pumps
Refrigerant Mixture Measurements in Two-Phase Flow
Refrigerator and Freezer Studies
Water Heater Studies
Furnace, Boiler, and Household Appliance Test Procedures
Appliance Standards
Household Appliance Data Update
Thermal Test Methods -- Solar Assisted Heat Pumps and Cooling Components and Systems
Experimental Evaluation -- Solar Test Cells
Technical Support to DoE

EVALUATING THE PERFORMANCE OF HEAT PUMPS

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Building Equipment Division

Sponsor: Department of Energy

The Department of Energy has undertaken an extensive heat pump development program for the past several years. The entire program involves several million dollars annually and has the development of several prototype innovative heat pumps as its goal. These prototypes may be segregated into two major categories: electric and heat actuated. The machinery development work is being conducted by several different industrial firms and the CBT role is one of independent technical evaluation of performance. CBT will develop the test and rating procedure under which each generic type of prototype can be evaluated in a laboratory.

For the advanced electric heat pumps, the test and rating procedure developed for DoE under the appliance labeling program appears to be adequate. Under the heat-actuated heat pump category, there are two subcategories: engine-driven heat pumps and absorption heat pumps. Under this program, CBT has already developed a test procedure covering the engine-driven units. The current fiscal year's efforts will focus on an evaluation procedure for absorption heat pumps. The data produced and techniques developed are essential if the true performance of equipment operating in the field is to be understood. This knowledge is then available for future use as the basis for improved equipment design, life cycle costing analysis, and establishment of minimum standards.

HEAT PUMP AND AIR CONDITIONER TEST PROCEDURES

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Sponsor: Department of Energy

The Energy Policy and Conservation Act (PL 94-163) and the National Energy Conservation Policy Act (PL 95-619) require the Department of Energy to prescribe test and rating procedures and minimum performance standards for various residential appliances, including central heat pumps and air conditioners. DoE has, since 1975, relied on CBT to assist in the development of the test procedures. Since then, DoE has been interested in verifying these test procedures and extending their scope to include new designs coming onto the market. Also, since the current procedures have caused a significant increase in the manufacturer's cost of testing, DoE is sponsoring a continuing CBT effort to simplify the procedures through better understanding (both analytical and empiricial) of this equipment's dynamic performance. This work encourages energy conservation affecting virtually all new-production residential heat pumps and air conditioners in the U.S.

EXAMINATION OF NON-AZEOTROPIC MIXTURE REFRIGERANTS FOR HEAT PUMPS

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Sponsor: Electric Power Research

Conventional vapor-compression heat pumps employ single-component refrigerants or azeotropic mixtures (those which have a single boiling-condensing temperature-composition phase diagram) as their working fluid. The use of non-azeotropic mixtures as the working fluid offers at least three potential energy performance advantages without major changes in the manufacturing process of existing heat pumps. These advantages are an improved capacity-to-power ratio, a reduction in irreversibilities in the heat exchangers, and an increase in capacity at lower evaporator temperatures. The quantification of each of these advantages can be estimated theoretically; however, the cost-effectiveness of the design changes can only be done by optimization studies by manufacturers who are thoroughly familiar with manufacturing costs. A tool for predicting the energy performance as well as the operating costs of a design is the simulation model being developed in this study.

REFRIGERANT MIXTURE MEASUREMENTS IN TWO-PHASE FLOW

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Sponsor: National Bureau of Standards

The convective heat transfer coefficient is the single most important property for the design of heat exchangers. For those heat exchangers which have internal boiling or condensation coupled with forced convection (e.g., refrigerant systems, steam power systems), the complexity of flow conditions are such that coefficient values are normally completely empirically based. Since this study focuses on binary mixtures which are non-azeotropic (different boiling/condensation points), the problem is complicated even further. In single-component fluids it is typical to establish an empirically based functional relationship between the convective heat transfer coefficient and the other transport properties (e.g., conductivity, visocity) for a given range of flow patterns and thermodynamic conditions. Once these relationships are established for categories of fluids, it is possible to predict the heat transfer coefficient based on the measurements of other transport properties that are significantly easier to make. In the area of nonazeotropic mixtures, virtually no such relationships among the transport properties exist.

The specific group of fluids that will be studied are fluorocarbons that are used or intended to be used as refrigerants. The apparent advantages of using non-azeotropic mixtures in refrigerant systems are improvement in efficiency, less environmental (ozone) impact, multi-level evaporators, and self-lubricating working fluids. The evaluation of any of these possible advantages entails an overall performance evaluation of the refrigerant system, which in turn requires knowledge of the transport properties of the refrigerant.

The heat transfer data and relationships that evolve from this study will be used by researchers in the refrigeration industry to quantify the advantages of binary mixtures in their future refrigeration systems design. Also, it will provide CBT with a measurement facility that is equally applicable to the wide variety of binary mixtures found in chemical plants.

REFRIGERATOR AND FREEZER STUDIES

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Sponsor: Department of Energy

DoE's effort in energy use labeling for household appliances requires that they have standard test procedures for accurate determination of energy efficiency, that the procedures are repeatable, and the procedures are not burdensome to perform. The objectives of this project then are to expand or modify the DoE test procedures for refrigerators and freezers where required and to provide laboratory data, analyses, and recommendations related to the new tests.

WATER HEATER STUDIES

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Sponsor: Department of Energy

The Energy Policy and Conservation Act (PL 94-193) has mandated that household appliances, including water heaters, be labeled for energy use using standardized testing methods. Thus, it is necessary to establish standard test procedures that allow the accurate determination of energy efficiency, are repeatable, and not burdensome to perform. The objectives of this project are to expand and/or modify the DoE water heater test procedures where required and to provide laboratory data, analyses, and recommendations related to the test procedures.

FURNACE, BOILER, AND HOUSEHOLD APPLIANCE TEST PROCEDURES

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Sponsor: Department of Energy

This project will provide industry, via DoE, with an equitable testing and rating procedure for determining the seasonal energy performance of central residential furnaces and boilers. The Energy Policy and Conservation Act (PL 94-193) and the National Energy Conservation Policy Act (PL 95-619) require the Department of Energy to prescribe test and rating procedures and minimum performance standards for various residential appliances, including furnaces and boilers. DoE has, since 1975, relied on CBT to assist in the development of these procedures. A draft test and rating document for furnaces and boilers was delivered to DoE in 1977. Final publication in the Federal Register was in May 1978. Since then, DoE has been interested in expanding the procedures to include new furnace designs coming on the market (i.e., condensing units) and adapting the test procedures to fit unusual designs (i.e., sealed combustion installations). During the course of this development, CBT has supported DoE in defending or modifying the procedures according to suggestions made by industry, who were concerned about every detail since virtually every furnace or boiler model sold in the United States will have to be rated in accordance with these procedures. This work will encourage energy conservation through the production of more efficient furnaces, boilers, and household heating equipment for residential space heating.

APPLIANCE STANDARDS

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Sponsor: Department of Energy

The Energy Policy and Conservation Act as amended by the National Energy Conservation Policy Act has mandated that national minimum efficiency standards be established to reduce energy usage. The legislation gives priority for establishing standards for eight products including refrigerators, freezers, room air conditioners, central air conditioners, furnaces, water heaters, clothes dryers, and kitchen ranges/ovens. Standards for the remaining product types are then to be established. These standards are crucial to the nation's goal of lower energy consumption. Technical support will be provided to DoE in their effort for developing energy efficiency standards for appliances.

HOUSEHOLD APPLIANCE DATA UPDATE

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Sponsor: Department of Energy

The Energy Policy and Conservation Act as amended by the National Energy Conservation Policy Act requires the development of test pocedures, labeling rules, and energy efficient standards for consumer appliances. These requirements must be established using representative data when reflecting such items as energy efficiency, energy use, etc. Many of the parametric values used in the initial rulemaking have changed due to energy price increases, changed consumer behavior, availability of more efficient appliances, etc. This project will develop the data needed to update the various rules promuglated by the Energy Conservation Program for Consumer Products using the most currently available data.

THERMAL TEST METHODS -- SOLAR ASSISTED HEAT PUMPS AND COOLING COMPONENTS AND SYSTEMS

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Sponsor: Department of Energy

This task draws on previous efforts in solar equipment and building equipment to develop viable test methods and evaluation procedures for solar-assisted heat pumps and solar cooling components and systems. Based on reviews of the work performed at CBT and elsewhere, as well as the eixsting industry consensus standards issued by ASHRAE and the Air-Conditioning and Refrigeration Institute (ARI), modified test methods and evaluation procedures will be drafted. Bench tests on candidate equipment will be conducted to verify the draft methods and to provide performance data for checking the evaluation procedures. An interagency report will be prepared for the sponsor summarizing the recommendations for test and evaluation procedures for these solar components.

EXPERIMENTAL EVALUATION -- SOLAR TEST CELLS

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Sponsor: Department of Energy

The objective of this project is to acquire data for use in 1) establishing performance monitoring procedures for passive solar heating and cooling systems; 2) performance characterization of various passive subsystems (e.g., clerestory, direct gain, sunspace, and collector/storage wall); 3) detailed passive solar building energy analysis and algorithm validation. Determination of the thermal performance of passive solar-heated and cooled buildings is important for designers and consumers to improve building energy efficiency, and for the Federal and State Governments to develop fair and effective regulatory and incentive programs. Passive solar thermal performance is inseparable from building thermal performance, which is complex and as yet not fully understood. Its determination can require instrumentation and analysis techniques. Improving consistency and uniformity will make performance evaluation results more credible to designers and consumers and more useful in estimating relative benefits between designs.

A passive solar test facility, for Class A level monitoring, has been constructed at the NBS annex in Gaithersburg, Maryland. This test facility has been especially designed to be reconfigurable so that different passive hybrid designs can be installed with minimum cost and effort. The current configuration hosts a direct gain cell, a control cell (i.e., no passive features), a trombe wall cell, and a cell housing the data acquisition system and a component testing calorimeter. The test facility has been operational since October 1981 with the direct gain cell completely instrumented and the control cell and trombe wall cell only minimally instrumented. Preliminary performance data for the direct gain cell for three different time sequences and test conditions have been gathered, reduced, and distributed to the participants of the Class A monitoring program.

Continuous air infiltration measuring equipment will be procured and installed at the test facility, and the instrumentation of the trombe cell will be completed. Carefully measured performance data for selected time sequences and test conditions will be acquired, reduced, and distributed to the participants of the Class A monitoring program.

TECHNICAL SUPPORT TO DoE

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Sponsor: Department of Energy

The Energy Policy and Conservation Act provides for the granting of waivers from testing for products which cannot be tested in accordance with the currently prescribed DoE test procedure. For DoE to respond to petitions from manufacturers for wavier, DoE must first resolve the question of applicability of currently prescribed test procedures to the products in question and then decide if waivers are to be granted or if testing under present test procedures is in order. CBT will provide DoE with the technical bases to make such decisions.

MECHANICAL SYSTEMS AND CONTROLS

Systems and Controls Laboratory
Controls Dynamic Modeling
Energy Monitoring and Control System Measured Performance
Energy Analysis of Control Strategies
Energy Monitoring and Control System Algorithms
Unsteady Hydraulics of Branch Drains and Soil Stacks
Existing Building Wiring Systems
Air Quality Criteria for Archival Storage

SYSTEMS AND CONTROLS LABORATORY

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Sponsor: National Bureau of Standards

The focus of this program will be developing mathematical models and measurement techniques for evaluating the performance of building systems and controls, encouraging energy conservation in buildings through improved control strategies and software, and developing guidelines for automated building management systems. This research effort will complement CBT's current DoE-sponsored research program aimed at documenting the energy saving potential of the most commonly employed HVAC control strategies, developing algorithms for building control systems, evaluating the reliability of automated building management systems, and studying the application of sensors in energy monitoring and control systems.

This year's effort will involve the development of a second-generation building/HVAC/control system simulation program for evaluating systems dynamics, algorithms, and strategies; the completion and use of an HVAC Test Facility for verifying and refining models and control algorithms; and the partial installation of CBT's own Energy Management and Control Systems in Building 101. Ultimately, the results of this work will be incorporated in future concensus standards, guide specifications, and design/operating aids for building designers, owners, and operators.

CONTROLS DYNAMIC MODELING

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Sponsor: U.S. Navy and Department of Energy

None of the building simulation programs (e.g., BLAST 2, DOE 2) in existence today account for HVAC control dynamics. As a result of this, there exists very little reliable data on the amount of energy waste in buildings due to control dynamics and absolutely no information on how to design and operate building control systems to optimize dynamic performance. This project will concentrate on developing simulation models that can be used to predict the dynamic, "minute-by-minute" performance of control systems for building air handlers and heating/cooling plants. This will cover controls for the most common types of HVAC systems and build upon on-going CBT research to develop simulation models for building equipment and systems. Research in future years will involve building dynamics, heating/cooling plant dynamics, and the simulation of the entire building/HVAC/control systems. New dynamic models and the information developed on HVAC/system control dynamics will lead to better building control system design.

ENERGY MONITORING AND CONTROL SYSTEM MEASURED PERFORMANCE

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Sponsor: U.S. Navy

This project will help the Navy in studying and improving the performance of EMC systems installed at naval facilities. Between 30 and 70 percent of the EMC systems installed in the U.S. are unreliable. This is due to many factors; one of the most significant problems is lack of knowledge by field personnel on how to purchase, install, calibrate, and maintain sensors and measurement instrumentation. Under this project, procedures for calibrating and verifying the accuracy of EMCS sensors in the field will be completed, and guidelines for the field calibration of building humidity, flow, and temperature sensors will be published. A sensitivity study on typical sensor errors will be completed and presented as an EMCS conference paper. Assistance will be provided the Navy in the review of work completed by an independent contractor in the development of an EMCS Inspection Testing Device. A study will also be undertaken to evaluate and document the effect of some typical HVAC/sensor/control system interactions on building energy consumption. Some typical interactions which might be investigated are: the effect of cooling coil throttling range on heat systems using economizer cycles; the application of economizer cycles to duel duct, multi-zone and variable air volume systems; the effect of pressure sensor error on the energy consumption of variable air volume systems; the retrofit of constant volume systems to VAV systems and correct pressure sensor location; and the effect of temperature sensor error on the control of hot and cold decks in multi-zone systems.

ENERGY ANALYSIS OF CONTROL STRATEGIES

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Sponsor: Department of Energy

A study is urgently needed to independently document the potential energy savings of different commonly used strategies. In FY82, CBT used the computer program BLAST 2 to evaluate control strategies for a variety of HVAC systems in a large office building and a large retail store in different regions of the country. Typical strategies studied were dry bulb economizer cycle, enthalpy economizer cycle, hot and cold deck temperature reset, zone control, floating space temperature, and scheduled setback. In FY83, this work was extended to cover control strategies for one additional building type (an education building). The building's performance is being simulated for several different types of HVAC systems and for seven different geographical locations, representing typical U.S. climatic regions. This study will encourage energy conservation by providing design engineers and building owners with factual information on the benefits of the most commonly employed control strategies. It will also lay the groundwork for the future development of an advanced analysis tool for evaluating control dynamics and advanced control strategies.

ENERGY MONITORING AND CONTROL SYSTEM ALGORITHMS

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Sponsor: U.S. Navy and Department of Energy

At present, there are no standardized, nonproprietary EMCS application algorithms available for use by companies entering the building controls field. Many of these companies lack training and experience in HVAC systems, building controls, and algorithm development. As a result, the building owner or manager who purchases their system is often stuck with an EMC system that either doesn't work or only partially works.

To assure a minimum level of performance of EMC systems, CBT plans to develop public-domain algorithms for HVAC/building applications. Work will concentrate on the completion of algorithms for the control of building air handlers, including optimal start/stop, scheduled time of day stop/start, duty cycling, demand limiting, temperature reset, and economizer cycle. In the second half of FY83, this effort will be expanded to development of algorithms for the control of heating and cooling plants.

The development of public domain algorithms for EMCS systems should greatly improve their performance, especially for systems made by small manufacturers, and lead to increased energy conservation in commercial buildings. Specification of such algorithms will help to assure that future energy measurement and control systems provide at least this minimum level of capability.

UNSTEADY HYDRAULICS OF BRANCH DRAINS AND SOIL STACKS

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Sponsor: National Bureau of Standards

The investigation of flows at the junctions between multistory drainage stacks and horizontal branches requires experimental measurements to determine inlet characteristics and the subsequent pipe flow conditions. Testing was begun during FY 1982 to provide soil stack exit and junction boundary conditions for later mathematical modeling. Numerical solutions of the flow equations of continuity and momentum as a function of dynamic load are to be obtained by expansion of the computer program for partially filled pipe flows, upstream and downstream of junctions; computations from the expanded program will be compared with experimental results.

The results will provide model plumbing code officials and plumbing design engineers with a new basis for code requirements and analysis of plumbing drainage systems. Traditional plumbing code requirements and design practices are based upon overly conservative tabulations of permissible pipe size loading tables derived from empirical factors for the hydraulic capacity. The American Society of Plumbing Engineers Data Book, "Fundamentals of Plumbing Design," does not provide an analytical technique for determining pipe size and slope for drains with low-water-usage fixtures. Dissemination of CBT reports and articles for inclusion in the Data Book can establish a broad capability to conduct trade-off studies to optimize drainage system installations, and through computer-aided graphics permit rapid determination of the performance of design variations.

AIR QUALITY CRITERIA FOR ARCHIVAL STORAGE

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Building Materials Division

Sponsor: General Services Administration

The National Archives Building, which houses many of the nation's basic documentary materials, was constructed in the early 1930's and was one of the first buildings in Washington to provide all-season environmental control. The controlled environment was prescribed to protect the nation's valuable records from the effects of extreme temperature and relative humidity, and from pollutants such as sulfur dioxide and nitrogen oxides. The original system, although designed to meet these objectives, has been modified over the years and has had a history of less-than-satisfactory performance.

Under this project, CBT will measure pollutants in the air at selected locations in the stack area of the National Archives Building to determine baseline performance of the existing environmental control system. Measurements will also be made in other buildings. Existing data of temperature and relative humidity conditions in the spaces used for records storage will be reviewed and additional data taken, if necessary, to determine current performance for thermal and humidity control.

A search will be made to determine the most up-to-date standards and "operating procedures" used in the design and maintenance of records storage facilities. Experts in the field of gaseous and particulate pollutants will be consulted to obtain their advice on the availability and acceptability of existing standards or the need to establish new limits for contaminates that accelerate degradation of historic artifacts and records. As a result of the investigation, criteria will be drafted for review by the National Archives which give recommended limits for control of environmental conditions. These criteria could be used as the basis for a GSA contract for upgrading the mechanical system of the building.

EXISTING BUILDING WIRING SYSTEMS

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Sponsor: Consumer Product Safety Commission

Existing wiring systems do in fact exceed the National Electric Code temperature limit of 60°C when covered with thermal insulation. The Consumer Product Safety Commission is concerned that long-term exposure to elevated temperature may pose a safety hazard for branch circuit wiring in homes. Following recommendations developed through an associated effort with CPSC, specimens of aged wire (rubber, polyvinyl chloride, armored cable, nonmetallic sheathed, and single strand) were identified. The ages of specimens were divided into three categories: pre 1940, 1940-1960, and post-1960. Before 1940, the wire was primarily rubber coated. From 1940 to 1960 there was a transition from rubber to PVC and since 1960 almost all production has been PVC. The Underwriters Laboratories under contract to CBT has been conditioning and testing the specimens, provided by CBT. The specimens are being conditioned at 60°, 75°, and 90°C. Measurement of tensile strength and elongation are made as a function of time and temperature. The data will be analyzed to determine if trends can be identified for the types of wire covering as the specimens are aged under the described conditions. If the data and the analysis produce results to indicate that at 60°C the dielectric insulating material is losing critical physical properties, a basis will exist for making recommendations for a code change.

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National Engineering Laboratory

Center for Building Technology