1981 BUILDING TECHNOLOGY PUBLICATIONS

U.S. Department of Commerce
National Bureau of Standards
Special Publication 457-6

NATIONAL BUREAU OF STANDARDS

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Linda Beavers, Editor

Center for Building Technology
National Engineering Laboratory
National Bureau of Standards
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INTRODUCTION

This report presents the National Bureau of Standards' Center for Building Technology (CBT) publications for 1981. It is the sixth supplement to NBS Special Publication 457, *Building Technology Publications 1965-1975,* and lists CBT documents issued or recorded during the period January 1 to December 31, 1981. It includes titles and abstracts of each NBS publication and each paper published in non-NBS media, key word and author indexes, and general information and instructions on how to order CBT publications.

This report communicates the results of CBT research to various technical audiences, as well as to the general public. Publications constitute a major end product to CBT's efforts and, in 1981, appeared in several NBS publication series (Building Science Series, Technical Notes, Handbooks, Special Publications, NBS Interagency Reports, Grant/Contract Reports and the Journal of Research) as well as in non-NBS media such as technical and trade publications. Publications appearing in non-NBS media have each been assigned a five-digit number. NBS publication series abbreviations are:

BSS - Building Science Series

TN - Technical Note

H - Handbook

SP - Special Publication

NBSIR - National Bureau of Standards Interagency Report

GCR - Grant/Contract Report

J. Res. - Journal of Research

This document is divided into three main sections. The first, *Titles and Abstracts,* provides the report title, author(s), date of publication, selected key words, and an abstract of each NBS publication and each paper published in an outside source. The *Author Index* cites each CBT author and gives the publication title and/or number referencing documents listed in this supplement. The *Key Word Index* is a subject index, listing word summaries of the building research topics for eah publication and paper. By selecting a main word or subject, which are listed alphabetically, the user is able to locate reports of interest through the subject-related words found in the key word index.

CBT is part of the National Engineering Laboratory, National Bureau of Standards. NBS undertakes basic and applied research in various areas. Interested readers will find other NBS publications listed in NBS Special Publication 305-13, *Publications of the National Bureau of Standards 1981,* from which parts of this report have been taken.

BUILDING SCIENCE SERIES

Building Science Series reports disseminate technical information developed at the Bureau on building materials, components, systems, and whole structures. The series presents research results, test methods, and performance criteria related to the structural and environmental functions and the durability and safety characteristics of building elements and systems.

BSS130. Elder, J.; Tibbott, R. L. **User acceptance of an energy efficient office building—A study of the Norris Cotton Federal Office Building.** *Nat. Bur. Stand. (U.S.) Bldg. Sci. Ser. 130;* 1981 January. 122 p. SN003-003-02278-1.

Key words: energy conservation; lighting; man/environment research; noise; office building; post-occupancy evaluation; questionnaire; temperature; ventilation; windows.

The General Services Administration built the Norris Cotton Federal Office Building in Manchester, New Hampshire, and chose it as a "demonstration project for studying the effectiveness of energy conservation techniques in the design and operation of a contemporary office building." User acceptance of both the innovative and conventional design features in the building was measured by administering a questionnaire to employees shortly after occupancy of the building and again eight months later. The most positively rated feature overall was the lighting, but reaction to the high pressure sodium lighting system as installed in the Norris Cotton Building was strongly negative. Response to noise levels and disturbances was about evenly divided, but workers in open-plan offices were less satisfied with the noise climate than workers in partitioned offices. Most respondents were dissatisfied with the temperature and ventilation conditions and the small windows in the building. In general, the occupants rated the building much higher in appearance than their previous offices, slightly higher in terms of suitability for performance of their jobs, and slightly lower with respect to comfort. A literature review of recent survey studies of the office environment is included.

BSS131. Knab, L.; Mathey, R.; Jenkins, D. **Laboratory evaluation of nondestructive methods to measure moisture in built-up roofing systems.** *Nat. Bur. Stand. (U.S.) Bldg. Sci. Ser. 131;* 1981 January. 173 p. SN003-003-02281-1.

Key words: built-up roofing electrical capacitance; infrared thermography; insulation; moisture detection; moisture measurement; nondestructive evaluation; nondestructive testing; nuclear backscatter; roofing systems.

This laboratory study investigated the reliability and accuracy of three types of nondestructive evaluation (NDE) methods to quantitatively determine the moisture content of the insulation in built-up roofing specimens. These methods were electrical capacitance, nuclear backscatter, and infrared thermography. Thirty-contents was induced into the specimens by maintaining a constant water vapor pressure difference across them.

Two performance characteristics of the NDE methods were evaluated: (a) the minimum moisture content a method could detect, and (b) the relationship between NDE response and moisture content beyond the minimum detectable moisture content. The two performance characteristics were assessed through normalization parameters defined in terms of the NDE response and its scatter about a fitted curve. There were differences in the performance characteristics, the magnitude of which depend on the NDE method, the specimen composition, and the deck type used.

BSS132. Yokel, F. Y.; Yancey, C. W. C.; Mullen, C. L. **A study of reaction forces on mobile home foundations caused by wind and flood loads.** *Nat. Bur. Stand. (U.S.) Bldg. Sci. Ser. 132;* 1981 March. 84 p. SN003-003-02301-9.

Key words: buoyancy forces; flood forces; foundations; hurricane forces; mobile home; soil anchors; standards; tiedown; wind forces.

Forces acting on the foundations of mobile homes subjected to wind and flood loads were calculated and are presented in a series of computer-generated charts. The loading conditions considered are the two levels of wind loads presently stipulated in the Federal Mobile Home Construction and Safety Standard, a hurricane windload recommended by the National Bureau of Standards (NBSIR 77-1289), buoyancy forces, and draft forces resulting from flood water flow. The calculated forces are compared with present anchoring requirements in ANSI Standard 119.3 (NFPA No. 501 A). It is concluded that diagonal ties are instrumental in resisting wind forces, and that vertical ties are more effective than diagonal ties in resisting flood forces.

BSS133. Hill, J. E.; May, W. B., Jr.; Richtmyer, T. E.; Elder, J.; Tibbott, R. L.; Yonemura, G. T.; Hunt, C. M.; Chen, P. T. **Performance of the Norris Cotton Federal Office Building for the first 3 years of operation.** *Nat. Bur. Stand. (U.S.) Bldg. Sci. Ser. 133;* 1981 August. 140 p. SN003-003-02352-3.

Key words: building models, computer; energy conservation in commercial buildings; energy conservation, user acceptance; lighting measurements; performance data for commercial office buildings in New England; solar energy in commercial buildings.

The Norris Cotton Federal Office Building is a medium-size seven-story Government office building of approximately 11,000 m^2 (117,000 ft^2) total floor area. It is located in Manchester, New Hampshire, and was designed to demonstrate a number of energy saving concepts.

Some of the major energy conserving features of the building are the use of solar collectors; heavy masonry construction with exterior insulation; small overall window area; heat recovery from heat pumps, chillers, a natural gas-powered engine/generator, and the ventilation system; modular boilers; thermal storage tanks; and a variety of energy conserving lighting systems.

A team from the Center for Building Technology, National Bureau of Standards (NBS), has been monitoring the performance of the building since it was occupied in September 1976. The project has involved not only an analysis of building energy consumption, but also a study of the effectiveness of the various lighting systems, a determination of the response of the occupants to the building, and a cost analysis of the construction and operation of an energy conserving building. This report will describe the building's performance for the first 3 years of operation.

BSS134. Petersen, S. R.; Barnes, K. A.; Peavy, B. A. **Determining cost-effective insulation levels for masonry and wood-frame walls in new single-family housing.** *Nat. Bur. Stand. (U.S.) Bldg. Sci. Ser. 134;* 1981 August. 126 p. SN003-003-02354-0.

Economically optimal insulation methods and resistance levels for three different types of walls in a one-story, single-family residence are calculated for a wide range of geographic locations, energy prices, heating and cooling equipment efficiencies, and financial evaluation criteria. The three basic wall types examined are 8-in concrete block walls, brick and block walls, and wood-frame walls with lightweight siding. Changes in annual heating and cooling requirements for an 1176 ft^2 prototype house resulting from several different insulation resistances in each wall type are calculated using the NBS Load Determination program and Test Reference Year climate data for a number of geographic locations. Changes in heating requirements are correlated with heating degree days to provide estimates of energy savings in all geographic regions of the continental United States. Cooling requirements are not found to vary significantly with the thermal resistance of the walls under a typical operating profile except in the southwestern desert. An index number system is developed to quickly determine insulation levels based on the data generated in the report.

BSS135. Kovacs, W. D.; Salomone, L. A.; Yokel, F. Y. **Energy measurement in the Standard Penetration Test.** *Nat. Bur. Stand. (U.S.) Bldg. Sci. Ser. 135;* 1981 August. 99 p. SN003-003-02356-6.

Key words: energy measurement; field instrument force measurement; field testing; in-situ testing; soil mechanics; transducers.

Geotechnical engineers in the United States commonly use the Standard Penetration Test, SPT, in subsurface investigation for routine foundation designs. It has been said that perhaps up to 80 to 90 percent of the routine foundation designs are accomplished by the use of the SPT "N" value. Despite efforts to standardize more details of the SPT procedure, variability between tests is inherent under present guidelines.

A field measurement system and procedure which measures the energy delivered by a drill rig system were developed and successfully used to study the factors which affect delivered energy. Results are presented which indicate the energy delivered by certain drill rig systems used in engineering practice. Also, the transmission characteristics of certain hammer/anvil systems are examined. Guidance on the need to measure the actual fall height of the hammer during the Standard Penetration Test is provided based on the findings of the study.

BSS136. Harris, J. R.; Wright, R. N. **Organization of building standards: Systematic techniques for scope and arrangement.** *Nat. Bur. Stand. (U.S.) Bldg. Sci. Ser. 136;* 1981 September. 278 p. SN003-003-02363-9.

Key words: arrangement; building; classification; code; engineering; organization; provisions; scope; specification; standard; system analysis/engineering.

Standards should be organized so that they provide reliable and quick access to the provisions of the standard. Organization is considered to deal with both the scope and the arrangement of the provisions of a standard. It is found to have objective qualities that allow it to be treated formally. Necessary and desirable qualities for an organization are identified, verified, and adopted as objectives and guidelines. The basic element of the system for organizing standards is the classification of the provisions of a standard. A faceted structure, providing a clear division between those levels that are strictly logical and those that are not, is recommended for the classification system. A relevant basis is found for classifying requirements using an idealized model of the relation between syntax and semantics. Development of the classification constitutes a formal treatment of scope. The classification is easily transformed into an index. Development of an outline from the classifiers constitutes a formal treatment of the arrangement. Criteria for placement of provisions in outlines and for construction of outlines from the classification are proposed to promote the objectives of organization. A computer algorithm for interactive outline generation is developed and evaluated. Measures are defined for the comparison of alternate outlines for the same standard.

TECHNICAL NOTES

Technical Notes present data which are complete in themselves but are not as comprehensive in scope or as definitive in treatment of the subjects as reported in Building Science Series.

TN1135. Rossiter, W. J., Jr.; Mathey, R. G.; Busching, H. W.; Cullen, W. C. **Cooling of bitumen during construction of built-up roofing systems—A mathematical model.** *Nat. Bur. Stand. (U.S.) Tech. Note 1135;* 1981 March. 76 p. SN003-003-02302-7.

Key words: bitumen application temperatures; bituminous roofing; built-up roofing; cooling of roofing bitumens; mathematical model; roofing.

Construction of bituminous built-up roofing systems in the United States generally involves the application of hot bitumen to the roofing components, including deck, insulation, and felts, to adhere them to each other and to form a waterproof membrane. Adequate adhesion of the bitumen to the roofing component materials may be obtained only when the hot bitumen is applied at a viscosity sufficient to flow uniformly, to cover the component surfaces or substrate completely, and to provide the proper thickness. During construction, rapid cooling of hot bitumen increases its viscosity significantly. If the viscosity becomes too high, poor adhesion between components, voids within the bitumen, and an excessive and non-uniform thickness of the bitumen may result.

This report describes a mathematical model based on finite-difference equations for calculating transient heat flow to estimate the cooling time of hot roofing bitumen. Estimates of the time required for hot bitumen to cool from its application temperature to 300°F (149°C) were computed as a function of material and environmental factors including: quantity of applied bitumen, bitumen application or contact temperature, air temperature, wind speed, and thermal properties of the bitumen and of the roofing components. The model was used to predict cooling times expected for hot asphalt applied to typical substrates with thermal properties representative of those of polyurethane foam and glass fiber insulation boards, insulating concrete, plywood, concrete, and steel decks, and roofing felt on decks or insulations. In addition, the model was used to predict cooling times for hot coal tar pitch applied to concrete and to felt adhered to glass fiber insulation. The results of the calculations demonstrate the widely-varying bitumen cooling times which depend upon the component material to which the bitumen is applied and the environmental conditions during application. Under certain environmental conditions, hot bitumen applied to some substrates cools extremely rapidly. In these cases, sufficient time for proper application may not be available.

TN1136. Waksman, D.; Streed, E.; Seiler, J. **NBS solar collector durability/reliability test program plan.** *Nat. Bur. Stand. (U.S.) Tech. Note 1136;* 1981 January. 85 p. SN003-003-02283-7.

Key words: accelerated aging; durability; environmental exposure; reliability; solar collectors; solar materials; stagnation testing.

The test program described in this plan is designed to evaluate both approved and proposed solar collector test procedures and to correlate laboratory, accelerated field and simulated operational exposures with actual field data.

The tests and exposure procedures described herein are intended to determine the influence of environmental exposure parameters that could affect the degradation of solar collectors and their materials. They are also intended, to the extent possible, to provide a correlation between changes that occur at the materials and the collector component levels. It is expected that the data obtained through their use will lead to more meaningful reliability/durability tests for solar collectors and their materials.

A wide variety of commercially available solar collectors and multiple material coupons of collector components are being tested at sites in different climatic regions. Appropriate laboratory tests are being conducted during the same time frame to determine physical and material properties for comparison with field test data and operational collector experience. The data obtained from these tests will be analyzed and correlated with that obtained from the current Government Demonstration Program and other related Government-sponsored programs.

TN1138. Kusuda, T.; Bean, J. W. **Savings in electric cooling energy by the use of a whole-house fan.** *Nat. Bur. Stand. (U.S.) Tech. Note 1138;* 1981 May. 39 p. SN003-003-02317-5.

Key words: building thermal performance; energy calculation; energy conservation; thermal comfort; whole-house ventilation.

Hour-by-hour cooling performances of a typical ranch house, with and without the use of a whole-house fan, were compared for the climate conditions throughout the contiguous United States. The comparative analyses were made by the use of NBSWHF, a modified version of NBSLD, to simulate the complex thermal coupling of whole-house-fan ventilated attic space. The calculations were performed for two operational modes: a cyclic fan mode and a stepwise continuous mode. The calculation predicted a large cooling energy savings as compared to the house without the use of the whole-house fan, without significant deterioration of indoor thermal comfort.

TN1139. Collé, R.; Rubin, R. J.; Knab, L. I.; Hutchinson, J. M. R. **Radon transport through and exhalation from building materials: A review and assessment.** *Nat. Bur. Stand. (U.S.) Tech. Note 1139;* 1981 September. 101 p. SN003-003-02360-4.

Key words: buildings; concrete; diffusion; exhalation; materials; measurement; permeability; radon; transport.

This report was prepared, at the request of the U.S. Environmental Protection Agency, for the purpose of reviewing, assessing, and summarizing what is currently known about radon transport through and exhalation from building materials. In four chapters, the report 1) considers the routes of entry of radon into buildings, describes the basic models for radon transport through building materials, critically reviews the small number of existing values for the necessary transport coefficients, and summarizes the solutions of both steady-state and time-dependent transport cases; 2) reviews and considers how the microstructural properties and internal characteristics of building materials may affect the transport and exhalation of radon; 3) considers the exhalation process from a more macroscopic, phenomenological viewpoint, and summarizes selected experimental data on radium concentrations in building materials, radon flux and exhalation from soils and building materials, and the effects of meteorological variables on radon exhalation; and 4) reviews and assesses various measurement methodologies that are used for laboratory and *in situ* studies of radon transport and exhalation. Needs for further research in each area are also recommended.

TN1140. Streed, E.; Waksman, D. **Uncertainty in determining thermal performance of liquid-heating flat-plate solar collectors.** *Nat. Bur. Stand. (U.S.) Tech. Note 1140;* 1981 April. 97 p. SN003-003-02306-0.

Key words: collector rating; measurement; solar collector; standards; thermal performance; uncertainty.

Thermal performance measurements of eight liquid-heating flat-plate solar collectors were conducted with two to four collectors of each type at four outdoor test sites. Tests were performed in accordance with the procedure prescribed by ASHRAE Standard 93-77. Statistical analysis of data sets for each collector type *within* test sites and *between* test sites was done using ASTM recommended methods to evaluate test method measurement uncertainty. Illustrations of the influence of thermal performance data uncertainty are presented for collector material degradation, collector rating and calculated system performance.

TN1143. Yonemura, G. T. **Visual acuity testing of radiographic inspectors in nondestructive inspection.** *Nat. Bur. Stand. (U.S.) Tech. Note 1143;* 1981 June. 29 p. SN003-003-02330-2.

Key words: acuity tests; nondestructive testing; quality testing; radiograph evaluation; visual inspection; visual testing.

Visual acuity tests for radiographic inspectors should be correlated with the type of tasks encountered in real world radiography. The testing procedures should be capable of assessing differences in day to day performance of a given inspector as well as the performance of one inspector relative to other inspectors. Single line targets with specific parametric values for contrast, width, and blur are recommended to provide a means for testing a radiographic inspector for visual acuity. These targets may be used for periodic tests by the employing organization or for more frequent self testing by the inspector. Statistics from the National Health Survey, procedures recommended by the NAS-NCR Committee on Vision and real world radiographs have been utilized in arriving at recommended test configurations.

TN1146. Jenkins, D. R.; Mathey, R. G.; Knab, L. I. **Moisture detection in roofing by nondestructive means—A state-of-the-art survey.** *Nat. Bur. Stand. (U.S.) Tech. Note 1146;* 1981 July. 82 p. SN003-003-02340-0.

Key words: built-up roofing; moisture; moisture detection; nondestructive evaluation; nondestructive testing; roofing; thermal resistance.

A literature survey is presented of nondestructive evaluation (NDE) methods for detection of moisture in roofing systems. The methods discussed include the use of capacitance-radio frequency instruments, capacitance-microwave instruments, nuclear meters, and thermal infrared scanners. For each method, the principles of operation are reviewed and the measured properties which are affected by moisture are identified. Factors other than moisture which may affect the response of the instruments are also described for each method. These factors produce responses which are similar to those due to moisture and include non-uniformities in the roofing system, roof construction details, and building equipment. The use of each NDE method in actual moisture surveys is reviewed.

It is emphasized in the report that the validity of roofing moisture surveys depends on both a knowledge of the factors noted above and a familiarity with roofing practice. Furthermore, cores of the roofing system at selected points are needed to confirm NDE observations.

To define operating conditions for infrared scanners, calculated temperatures of roof surfaces over dry and over wet insulation are presented for representative night and day conditions.

TN1148. Treado, S.; Kusuda, T. **Solar radiation and illumination.** *Nat. Bur. Stand. (U.S.) Tech. Note 1148;* 1981 November. 31 p. Available from: NTIS; PB 82-135823.

Key words: daylighting; illuminance; illumination; irradiance; solar radiation.

Experimental data were collected and analyzed under various cloud cover conditions to establish the relationship between solar irradiance and illuminance. Empirically derived equations are presented for estimating diffuse and total illuminance as a function of total and diffuse solar radiation.

TN1149. Campbell, P. G.; Martin, J. W.; McKnight, M. E. **Short-term evaluation procedures for coatings on structural steel.** *Nat. Bur. Stand. (U.S.) Tech. Note 1149;* 1981 September. 43 p. SN003-003-02367-1.

Key words: accelerated aging tests; coatings; corrosion; predictability; reproducibility; time to failure.

This report presents the findings of the first of a two-phased study to aid the Federal Highway Administration in evaluating and selecting protective coatings for steel. The objectives of the study are to review existing short-term test procedures for selecting coatings, and to discuss analytical measurement techniques for characterizing coating systems and for monitoring coating degradation.

In assessing current accelerated aging testing procedures, several deficiencies became apparent. These included the reported lack of reproducibility in the rankings for different iterations of the same short-term test and the lack of correlatability between the rankings of short-term laboratory and long-term outdoor exposure tests.

It was concluded that, at the present time, coating manufacturers and users do not depend heavily on accelerated test results for making durability assessments. Instead durability assessments are based on outdoor exposure performance. Recommendations are made to design future short-term test procedures using reliability theory.

TN1152. Pommersheim, J. M.; Mathey, R. G. **Mechanical performance of built-up roofing membranes.** *Nat. Bur. Stand. (U.S.) Tech. Note 1152;* 1981 December. 60 p. Available from: NTIS; PB 82-151259.

Key words: adhesive; bitumen; bonding; built-up roofing membrane; complementary strain energy; felt; nonlinear; roofing membrane; splitting; strain energy; stress; substrate.

For built-up roofing membranes with either linear or non-linear stress-strain behavior, fully bonded to an underlying deck or substrate which undergoes displacement, it is the equality of the complementary strain energy of the fabric or felt layer with the strain energy of the bonding adhesive or bitumen layer, which governs both the conditions under which membrane integrity is lost and the mode of failure by either membrane splitting or adhesive bonding. The testing criteria developed are applied to a sample case.

HANDBOOKS

Recommended codes of engineering and industrial practice (including safety codes) developed in cooperation with interested industries, professional organizations, and regulatory bodies.

H135. Ruegg, R. T. **Life-cycle costing manual for the Federal energy management programs.** *Nat. Bur. Stand. (U.S.) Handb. 135;* 1980 December. 234 p. SN003-003-02274-8.

Key words: cost effectiveness; economic evaluations; energy conservation; Federal energy management program; life-cycle costing; public buildings; renewable energy; solar energy; solar photovoltaic.

This manual is a guide to understanding the life-cycle costing method and an aid to calculating the measures required for evaluating energy conservation and renewable energy investments in all Federal buildings. It expands upon the life-cycle costing criteria contained in the Program Rules of the Federal Energy Management Program (Subpart A of Part 436, Title 10, U.S. Code of Federal Regulations) and is consistent with those criteria. Its purpose is to facilitate the implementation of the Program Rules by explaining the life-cycle costing method, defining the measures, describing the assumptions and procedures to follow in performing evaluations, and giving examples. It provides worksheets, a computer program, and instructions for calculating the required measurements.

The life-cycle costing method and evaluation procedures set forth in the Federal Energy Management Program Rules and described in greater detail in this guide are to be followed by all Federal agencies for all energy conservation and renewable energy projects undertaken in new and existing buildings and facilities owned or leased by the Federal government, unless specifically exempted. The establishment of the methods and procedures and their use by Federal agencies to evaluate energy conservation and solar energy investments are required by Section 381(a)(2)of the Energy Policy and Conservation Act, as amended, 42 U.S.C. 6361(a)(2); Section 10 of Presidential Executive Order 11912, amended; and by Title V of the National Energy Conservation Policy Act, 92 Stat. 3275.

SPECIAL PUBLICATIONS

This series includes proceedings of conferences sponsored by the Center and other special publications appropriate to this grouping including project summaries, list of publications, wall charts, pocket cards, and bibliographies.

SP446-5. Raufaste, N.; Olmert, M., eds. **Building technology project summaries 1980-1981.** *Nat. Bur. Stand. (U.S.) Spec. Publ. 446-5;* 1981 July. 82 p. SN003-003-02343-4.

Key words: building research; building technology; codes; criteria; measurement methods; performance criteria; project summaries; technical bases.

The Center for Building Technology provides the technical and scientific bases for criteria and standards that improve the usefulness, safety and economy of buildings while conserving building materials and energy. The Center's activities support building technology programs of the Federal, State and local governments; assists design professions, building officials and the research community by developing design criteria that improve buildings; and assists manufacturers of building products by developing criteria for evaluating innovative building materials. This report summarizes the Center's projects for calendar year 1980-81. It enables individuals to get a clear impression of CBT research activities.

SP457-5. Webber, S., ed. **Building technology publications 1980—Supplement 5.** *Nat. Bur. Stand. (U.S.) Spec. Publ. 457-5;* 1981 June. 90 p. SN003-003-02332-9.

Key words: abstracts; building technology; Center for Building Technology; key words; publications.

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SP480-37. Rubin, A. I.; Howett, G. L. **Emergency vehicle warning systems.** *Nat. Bur. Stand. (U.S.) Spec. Publ. 480-37;* 1981 May. 25 p. SN003-003-02323-0.

Key words: conspicuity; effective intensity; emergency warning lights; flashing lights; lights, warning; sirens; sound level; warning light; warning signals.

The subject of visual and auditory warning devices (lights and sirens) for emergency and service vehicles is surveyed from a broad perspective. It is intended that this user guide should provide directly useful information at all levels from the selection of hardware to an understanding of the psychophysical factors determining the effectiveness of these devices. Topics covered include: the theory of warning signals; the present situation and the need for uniform national standards; suggested performance standards for warning light systems and for sirens, including the reasons for the principle requirements; recommendations for actions that can be taken to improve the signal effectiveness of emergency vehicles; an illustrated classification of the many types of emergency-vehicle warning lights; and brief summaries of some of the physical measurements that were made on a selection of lights and sirens.

SP606. Trechsel, H. R.; Launey, S. J. **Criteria for the installation of energy conservation measures.** *Nat. Bur. Stand. (U.S.) Spec. Publ. 606;* 1981 July. 203 p. SN003-003-02337-0.

Key words: automatic ignition devices; caulks; effectiveness; energy conservation; energy conservation measures; installation; insulation; oil burners; practices; safety; sealants; standards; storm doors; storm windows; vent dampers; water heaters; windows.

Standard installation practices were developed to assist in assuring the effectiveness and safety of energy conservation measures installed under the Residential Conservation Service (RCS). They serve as mandatory standards under RCS but are recommended guides for all installations of the covered materials and products. The criteria are being used by DoE to develop training manuals for installers, inspectors, and energy auditors.

Part I provides information on the intended use of the practices, outlines the RCS program, and discusses specific major technical and related issues that were considered in the development of the standards: moisture and building retrofit, attic ventilation, electrical wiring, recessed and surface-mounted fixtures, the use of diagnostic tools (infrared thermography, air change rate, and window air leakage measurements), and product certification.

Part II provides the actual practices together with commentary and additional recommendations. The products covered are loose-fill, batts and blankets, rigid foam boards, UF foam and reflective insulations, window devices, caulks and sealants, water heater insulation, oil burner replacements, and vent dampers.

SP608. Berry, S. A., ed. **Research and innovation in the building regulatory process.** Proceedings of the Fifth Annual NBS/NCSBCS Joint Conference Technical Seminar on Solar Energy and Energy Conservation; 1980 August 6; Denver, CO. *Nat. Bur. Stand. (U.S.) Spec. Publ. 608;* 1981 May. 201 p. SN003-003-02321-3.

Key words: ASHRAE 90-75; class K code; computer modeling; electrical design; energy audit; energy conservation; HVAC systems; performance standards; solar collector; solar energy; space heating and cooling; thermal storage.

The Proceedings of the Fifth Annual NBS/NCSBCS Joint Conference on Research and Innovation in the Building Regulatory Process contain 17 technical papers. This year's joint conference addressed solar energy and energy conservation.

These proceedings include papers on: Energy programs in the State of Colorado; Building energy performance standards concepts; State energy audits; Energy and building systems services; Solar energy and building codes. *These proceedings include the following papers (indented):*

SP608; 1981 May. 21-35. Emery, A. F.; Dorri, B.; Kippenhan, C. J.; Heerwagen, D. R.; Banken, G. **Alternate optimal control strategies for residential HVAC systems.**

Key words: cost savings; energy conservation; HVAC systems; innovation; mathematical model; optimization.

The optimal control of HVAC systems on an hourly basis is determined both by the thermal inputs which precede the hour under question and by future thermal effects. Most simulation programs treat only the past history. This paper describes results obtained with a special program which optimizes the use of the HVAC system in conjunction with natural and artificial lighting and with other thermal load schedules by considering such future effects.

The results indicate that substantial savings can occur through such a look-ahead optimization and that the extent of the needed future knowledge for most residential structures is in the neighborhood of a few hours. It is also shown that such an optimization is more valuable for the gradual changes associated with the usual weather than with rapid changes of internal thermal loads.

SP608; 1981 May. 37-56. Zackrison, H. B., Jr. **Energy conscious electrical design.**

Key words: electrical design; energy distribution; National Electrical Code; power factor correction; source energy; transformers.

Concern over the adequacy of future energy resources has led the Federal Government to require States to adopt energy conservation techniques for all new construction. Different approaches have been tried, such as Resource Utilization Factors, which consider how efficiently one source of energy can be converted into another (i.e., 3.04 Btus of heat energy are required to produce and transmit 1 Btu of electrical energy to the point of use); and Resource Impact Factors, which consider the relative availability and renewability of a fuel.

The Department of Energy's current approach centers around the formulation of Building Energy Performance Standards, which prescribe energy consumption goals for various types of structures in different climates while allowing designers to achieve these goals in their own ways.

Thus, this paper will consider a number of electrical design techniques that contribute to minimizing energy consumption and maximizing the efficiency of electrical installations. Some of the techniques discussed also involve the source concept, as opposed to the boundary concept, of energy conservation: reducing the total energy expenditure required to construct buildings by minimizing the quantities of raw materials and finished products required.

SP608; 1981 May. 57-67. Kainlauri, E. O. **Potential energy savings in buildings resulting from the NCSBCS code compared with BEPS.**

Key words: building code; building envelope; comparison; compliance; energy budget; energy conservation; performance standards; Statement of Review; verification.

In the State of Iowa, under the present State Energy Conservation Building Code (National Conference of States on Building Codes and Standards [NCSBCS] Code), all buildings that are larger than 100,000 cubic feet must be submitted for

State approval, with a statement from a registered architect or engineer verifying that the plans and specifications meet the code requirements. During the past 2 years, more than 100 design professionals and about as many building inspectors have completed a training course organized by the Architecture Extension of the Iowa State University (ISU), and more than 400 building plans have been submitted to the Iowa Building Code Commission for approval. The required "Statement of Review" includes design conditions and overall U-values for exterior walls, roof/ceilings, floors, and the gross wall cooling thermal transfer value (OTTV).

During the 2 years since the code was introduced, some 412 buildings have been analyzed by the ISU Architecture Extension as to what degree the results compare with the corresponding code requirements. It was found that the results are encouraging. By an average, the U_o wall figures are about *40 percent better* than the allowable American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 90-75 standards (or the revised ASHRAE 90.1-75R), the roof/ceiling values about 15 percent, and the OTTV values more than 50 percent better.

For the purpose of comparison with the Building Energy Performance Standards (BEPS), the results have been classified in 17 categories in anticipation of BEPS categories (splitting office buildings into large and small categories). The results illustrate characteristically how buildings of various types may approach or even exceed BEPS values. Of course, the U_o-values by themselves cannot be compared directly with BEPS performance standards and energy budgets, but a close implication can be seen from values produced by approximation.

As a second phase of the research, the Architecture Extension has been checking sample building plans in various parts of the State, in order to verify the accuracy of statements submitted. So far, the statements have been proven accurate, with only minor computation errors. Later on, another check is planned inspecting those buildings for actual installations. Finally, energy audits are planned for verification of performance criteria. The ISU Building Energy Utilization Laboratory is also involved in studies of Iowa buildings.

SP608; 1981 May. 69-81. Loxley, T. E. **Solar and geothermal housing innovations via inverted cave construction system.**

Key words: buildings; construction; energy conservation; ground coupled; hybrid solar energy system; inverted cave; low grade geothermal; radiant floor heating; space heating and cooling; thermal mass; walls; water source heat pump.

The cave offers many energy saving advantages, but the problems of underground construction severely limit its application. The author shows that modern materials can be used to build a house on grade as though it were a cave turned inside out. The result is a house of generally conventional appearance that functions like a cave.

The system consists of a highly insulated exterior wall and roof surrounding a central core of high thermal mass. Insulation extending to the base of the foundation isolates the house from outside temperature fluctuations. A concrete floor and central masonry wall then thermally couple the home interior to the underlying subsoil.

Reduced heating and cooling loads and the nature of the design introduce climate control options not possible with conventional construction. A piping loop placed directly beneath the slab floor permits the storage and circulation of water for use with a highly efficient water source heat pump. A modestly sized solar array is used in a simple, attractive arrangement to heat the loop water. This provides a radiant floor heating effect and boosts system efficiency.

Readily compatible with today's quality builders, this versatile system concept costs little more than current energy wasting construction.

SP608; 1981 May. 83-103. Forest, A. **Basic human values and energy conserving lifestyles or the implications of California's innovative new Class K code.**

Key words: alternative; California; Class K code; conservation; discrimination; energy; United Stand.

This report stresses the energy conserving implications of California's innovative new "Class K" code provision for primitive architecture and alternative technologies. The philosophy of United Stand, proponent of the "Class K" code, is here highlighted in the interest of energy conservation, and owner-builders across America who wish to maintain basic human values and energy conserving lifestyles.

We now propose a similarly conceived national code that will specifically mandate the right of owner-builders to employ alternative technologies in their own homes—a new code which will spell our functional performance rather than prescribe specific technology; a code written briefly, and simply, to provide a rule of thumb, rather than repression; a code which will legalize and facilitate low-cost, low-technology, energy-efficient housing, rather than discriminate against it. We ask for a code specifying the right of homeowner-builders to turn "OFF" a portion of our Nation's energy—their own.

SP608; 1981 May. 105-112. Lord, D. **Setting standards for building energy performance in Hawaii.**

Key words: building energy performance; codes; energy conservation; energy policy; Hawaii; performance standards.

The State of Hawaii is unique in its energy supply and energy consumption patterns. Precariously dependent on imported petroleum, Hawaii has the potential for meeting much of its energy needs through the development of its solar, wind, geothermal, and ocean resources. These issues will play important roles in the formulation of policy in the statewide approach to energy conservation in buildings. The proposed Building Energy Performance Standards (BEPS) and the existing American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 90-75 standard have raised questions among design professionals and at the State planning level about appropriate climatic criteria, design energy budgets and weighting factors for fuels. The climate of Hawaii was not represented in the Baseline Energy Study by the American Institute of Architects (AIA) Research Corporation and does not appear in the list of Standard Metropolitan Statistical Areas (SMSA) in the Notice of Proposed Rulemaking for BEPS. Weighting factors developed by the U.S. Department of Energy (DoE) for the various fuels used for lighting, cooling, and water heating seem to be inappropriate for Hawaii.

A modified BEPS approach is proposed which would probably offer advantages over the present ASHRAE 90-75 based building code. This would encourage the use of renewable energy and passive techniques in meeting design energy budgets and in reducing the State's dependence on imported fossil fuels.

SP608; 1981 May. 113-122. Anderson, J. M.; Evans, P. M.; Smith, R. L. **A simplified low cost technique for evaluating building energy performance standards submittals.**

Key words: BLAST; building energy performance standards; computer modeling; maintain accuracy; reduce cost; reduce input; standard evaluation technique.

The Building Energy Performance Standards propose a "Standard Evaluation Technique" based almost entirely on the modeling of energy performance by computer techniques. This modeling requires elaborate data, manipulation of complex data bases, large amounts of memory, and is feasible only with the latest in computer technology. Currently, where such technology is available, its use is prohibitively expensive.

A study was made on the University of Illinois CYBER 175 computer using an energy analysis program similar to the one required by BEPS. This study found, for the test case, that lines of input could be reduced by up to 77 percent, that the number of surfaces needed to describe the building could be reduced by 80 percent, and that the computer cost of running this analysis

could be lowered by 75 percent. It was found that all of these reductions could be made and still maintain a high degree of accuracy (within six percent) as compared to the thorough base run.

The results indicate a large potential for the reduction of building code officials' time in preparing the computer input and for the reduction in cost for running such energy evaluation programs on large computers.

SP608; 1981 May. 123-132. Glickman, D. S.; Terry, D. L. **Energy audits of public buildings in Illinois.**

Key words: cost; construction; energy audit; energy conservation; Illinois; maintenance; public buildings; state government.

The Illinois Capital Development Board is a State governmental board which manages the construction of $200-400 million of public buildings and related facilities per year.

This paper will discuss the technical experience gained in the energy audit program wherein approximately 277 public buildings have been audited and recommendations made to change operating and maintenance procedures and make construction changes. When implemented, the changes, estimated to cost $5 million will save approximately $75 million over a 15 year period.

Types of buildings audited to date include dormitories, schools, dietary facilities, hospitals, offices, steam generation plants, and general and mechanical stores. Approximately 10.3 million gross square feet (GSF) have been audited. The largest building audited was 444,000 GSF, the smallest 1500 GSF.

The cost of performing the audits is, on the average, repaid in 2 years by the savings realized from implementation of recommended operating and maintenance changes alone. This program was praised by Region V U.S. Department of Energy (DoE) Headquarters, Chicago, Illinois.

Also discussed will be the Technical Research Unit, its energy functions and goals.

SP608; 1981 May. 133-138. Kainlauri, E. O. **A professional approach to class A and school and hospital energy audits, with case studies.**

Key words: certification; Class A energy audit; economic analysis; energy analysis; energy conservation; Federal programs; government buildings; hospitals; rate of return; schools; technical assistance.

The State of Iowa has probably one of the toughest but most appropriate programs of Class A Energy Auditor Certification. As a first requirement the applicant must be either a registered architect or engineer. Secondly, he or she must take a 3-day training course organized by an advisory committee composed of representatives from the professions and industry and from the Iowa State University (ISU), and finally pass an all-day test which includes a partial energy audit with instrumentation. The training courses have been given seven times since late 1978, and additional courses are scheduled in the future. Nearly 200 Class A Energy Auditors have so far "graduated." Special courses are also given on school and hospital energy auditing. The first part of this paper will deal with the training aspects and requirements.

The second part of the paper will concentrate on results of these audits which are both quantitative and qualitative. Several hundred energy audits on government buildings, schools, and hospitals have taken place, partly financed by Federal programs. Information on Iowa buildings is being computerized and analyzed.

At a recent case study workshop, specific aspects were highlighted, including a number of building environmental topics, decision making criteria, computer applications, audit procedures, cost of audits and energy conservation measures, and codes and standards. The impacts on finances, building energy consumption, personnel, and the profession were discussed. Means to improve results of future energy audits by sharing experiences was the main objective. The results are encouraging.

SP608; 1981 May. 139-157. McCarney, S. **A simplified procedure for the use of solar energy in complying with the Colorado energy conservation standards for residential buildings.**

Key words: BEPS; code compliance; code conflicts; energy conservation standards; solar energy; trainee performance testing.

This study reviews the history of the residential energy conservation building standards in Colorado. Attendant educational efforts are described. Results from performance testing of trainees are presented. Numerous sources have requested simplified code compliance methodologies. Presented is a simplified strategy for code compliance through the use of solar energy. Code conflicts with solar are identified. The effects of the Building Energy Performance Standards (BEPS) on solar use are briefly discussed.

SP608; 1981 May. 159-166. Gaines, R. S.; McLafferty, P. S. **Solar systems facilitated by the proper application of existing building codes.**

Key words: building codes; building officials; codes and standards; convective loops; greenhouses; heat exchangers; light and ventilation; solar systems; space heating and cooling; training programs.

The California Energy Commission (CEC) and the California Building Officials, Inc. (CALBO) have jointly developed a manual designed to assist local building officials in identifying, understanding, and completing a code analysis of solar systems presented to building departments for permit approval. Published by the International Conference of Building Officials (ICBO), the *Solar Systems Code Review Manual* provides both building departments and builders a set of clear guidelines to be followed by specifying the code sections which will be applied in the plan check and inspection processes. The manual is based on the rationale that the plumbing, structural, electrical, and mechanical components of both solar and conventional space conditioning and water heating systems are largely similar and can, therefore, be regulated by existing codes and standards. Several code items have been identified which, if rigidly enforced, could serve to inhibit the implementation of solar systems, and a process has been developed for resolving such problems without sacrificing important health and safety standards.

SP608; 1981 May. 167-172. Trant, B. S. **Development of recommended requirements to code officials for solar heating, cooling and hot water systems.**

Key words: building codes; building officials; consensus; construction; document; installation; recommended requirements; solar energy; solar systems.

Under a Department of Energy contract, the Council of American Building Officials has developed "Recommended Requirements for Code Officials on Solar Heating, Cooling and Hot Water Systems." The recommended requirements treat all the major code categories—building, electrical and mechanical/plumbing.

These requirements will serve a guide for building code officials to judge the health and safety aspects of solar systems and their proper installations. Where requirements exist in a major model code they are referenced with commentaries provided for technical backup or where further explanation is needed.

The development of the recommended requirements through the consensus process is described.

SP608; 1981 May. 173-178. Williams, S. **A method for retaining an experimental attitude in solar codes.**

Key words: deed; developers; energy wars; experimental code; field test; guideline; low income; non-code; policymaking; protestors; solar code; victim role.

The viability of the incipient solar age will in large part be determined by humankind's ability to learn new technologies. The basis of leaning is being able to experience the failure or success of one's ideas. For innovative structures, the most direct and readily available means of experiencing their workability is to live in them. Proposed solar building codes are based on our existing solar methodology, thereby leaving little room for a person wanting to experiment with a new idea on his/her own home.

In order to solve the problem of the code becoming a barrier to further development of solar technology, the author proposes recording on the property deed a notation stating that the property has a building whose solar system is not according to code.

A 2-year field trial of the Recommended Requirements to Code Officials on Solar Heating, Cooling, and Hot Water Systems, developed by the Council of American Building Officials, is suggested to enable the public and building inspectors time to acquaint themselves with it and work out any bugs.

SP608; 1981 May. 179-181. Wrenn, P. **State Government roles in national solar collector labeling, certification, and rating.**

Key words: certification; consumer protection; Interstate Solar Coordination Council; labeling procedures; national testing program; regulation; solar collector; standards; voluntary program.

Dr. Ron Doctor of the California Energy commission and Dr. David Block of the Florida Solar Energy Center initiated a program in late 1979 to encourage reciprocity between states in their regulations concerning solar collector certification and labeling. Florida and California had both instituted testing and certification programs at that time which were required for their tax credits for solar devices and used for other regulatory purposes. Also, the Solar Energy Industries Association (SEIA) and the Air-conditioning and Refrigeration Institute (ARI) had come up with two additional labeling and certification programs. Potential confusion and duplication of effort seemed to be developing so a meeting was called of 25 States active in solar energy matters.

Several meeting have now been convened and remarkable progress has been made toward the goal of a single national program for rating, labeling and certifying solar collectors, and eventually, for complete solar systems. The four programs now in existence (both State and industry) were represented, as well as about 30 State solar offices which have been considering implementing such programs.

At an April 1980 meeting there was a preliminary agreement that there should be a single national system, run by a non-profit corporation with a Board of Directors composed of individuals nominated by SEIA and ARI and representatives of the State Government consensus effort initiated by Dr. Block and Dr. Doctor.

This paper details progress to date and projects completion dates for a national testing program, labeling program, and rating program for solar collectors. An applications manual is also planned, as well as additional work on systems and eventually certification.

SP608; 1981 May. 183-194. Key, W. P.; Potter, T. **Residential conservation service program solar model audit.**

Key words: auditor training; energy conservation; program measure; Residential Conservation Service; Solar Model Audit.

The Residential Conservation Service (RCS) has been developed by the Department of Energy (DoE) as a requirement of the National Energy Conservation Policy Act (NECPA). The goal of the program is to reduce non-renewable energy use in the Nation's homes through increased application of conservation methods and the use of solar and wind energy systems to displace conventional energy sources.

The DoE program includes development of a model audit to assist the States in preparation of the State plans for implementation of RCS. Oak Ridge National Laboratory managed the model audit development effort with the Solar Energy Research Institute (SERI) assigned responsibility for development of the solar and wind energy systems portions of the audit.

This paper discusses the solar model audit development and the potential impact for homeowners, utilities, and solar suppliers/contractors. An overview of the solar model audit reviews the regulation requirements pertinent to solar with emphasis on standards, warranties, and installation considerations. A discussion is presented on the program impact on utilities, especially with regard to identifying sufficient numbers of qualified auditors and the training of these auditors. The active and passive solar and wind energy portions of the audit are described including data bases used, assumptions for respective solar or wind system measures, and examples of the audit use on a field trial home.

SP608; 1981 May. 195-200. Heinemeyer, R. R. **Building codes vs. the design of passive solar heat storage.**

Key words: codes; concrete; masonry; prohibitions; re-examination; thermal storage; wood structure.

This paper explores the difficulties in complying with the major national building codes when designing thermal mass storage elements into a low-mass (wood frame), direct-gain passive solar building. Experience with one of the first pre-manufactured passive solar buildings in the United States (the Boise Cascade solar prototype house recently erected near Denver) is presented. Different strategies for the design of thermal mass elements and their acceptability to code administering authorities are discussed.

SP623. Pielert, J. H. **Removing regulatory restraints to building rehabilitation: The Massachusetts experience.** *Nat. Bur. Stand. (U.S.) Spec. Publ. 623;* 1981 October. 57 p. Available from: NTIS; PB 82-121047.

Key words: building code; building research; buildings; code enforcement; regulations; rehabilitation.

Throughout the United States, increasing concern is being expressed for the need to more fully utilize the existing building stock. The report documents a process that was initiated in late 1977 and continues to the present time in which particular regulatory problems impacting building rehabilitation were identified, a regulatory concept which responded to these problems was formulated, and the actual implementation of the new approach in the State of Massachusetts. Article 22 of the Massachusetts State Building Code is printed in the Appendix of the report and four case studies of actual buildings which were rehabilitated are included.

NBS INTERAGENCY REPORTS

The Interagency Reports are a special series of interim or final reports on work generally performed by NBS for outside sponsors (both government and non-government). When released by the National Bureau of Standards and the Sponsor, initial distribution is handled by the Sponsor. Public availability is by the National Technical Information Service (NTIS), Springfield, VA 22161. This series must be ordered from NTIS by the order number listed at the end of each entry.

NBSIR 79-1911. Maxwell, B. R. **Procedures for testing, rating, and estimating the seasonal performance of engine-driven heat pump systems.** 1979 September. 60 p. Available from: NTIS; PB 81-123564.

Key words: building heating and cooling; engine-driven heat pump; heating and cooling equipment; heating, ventilating and air conditioning; heat pump.

A generic test and rating procedure is developed for heat engine-driven air-to-air heat pump systems. The procedures are classified according to whether the systems have single-speed, two-speed, or variable-speed capability, and whether they are operating in the heating or cooling mode. The test requirements generally consist of a series of steady-state tests to establish the impact of outdoor temperature on performance, two or more part-load (cyclic) tests to determine the effect of "on-off" cycling, two steady-state intermediate speed tests to determine part-speed performance, and a single frost accumulation test to estimate the effect of frost. A generalized calculation and rating procedure is developed. The system is rated in both modes based upon its steady-state performance at the ARI standard rating points, its seasonal performance factor, and its seasonal operating cost. A frost degradation coefficient is also established. The seasonal parameters are based upon either a residential or commercial/industrial building application which is located in either a generalized northern or southern climate.

NBSIR 80-1979. Wright, R. N.; Fenves, S. J.; Harris, J. R. **Modeling of standards: Technical aids for their formulation, expression, and use.** 1980 March. 17 p. Available from: NTIS; PB 80-203581.

Key words: building standards; classification; decision tables; information networks; modeling; standards; standards-writers; systems analysis.

Standards are the primary communication and control mechanism used to describe building practices and products in communications between the various participants in the building process. Most prior research related to building standards has been concerned with understanding and improving the performance of building products. This work, in contrast, is concerned with improving the organization, expression and interpretation of the information contained in a standard. Techniques are described for objective and rigorous representation of the meaning of a standard. These allow it to be tested for aspects of clarity, completeness, consistency and correctness. Furthermore, the techniques allow alternative organizations and expressions to fit the needs of various users with assurance that meanings remain unchanged and that users will readily find and understand all provisions even in a new or unfamiliar standard.

NBSIR 80-1979-1. Wright, R. N.; Fenves, S. J.; Harris, J. R. **Modeling of standards: Technical aids for their formulation, expression, and use.** 1980 December. 17 p. Available from: NTIS; PB 81-159600.

Key words: building standards; classification; decision tables; information networks; modeling; standards; standards-writers; systems analysis.

Standards are the primary communication and control mechanism used to describe building practices and products in communications between the various participants in the building process. Most prior research related to building standards has been concerned with understanding and improving the performance of building products. This work, in contrast, is concerned with improving the organization, expression and interpretation of the information contained in a standard. Techniques are described for objective and rigorous representation of the meaning of a standard. These allow it to be tested for aspects of clarity, completeness, consistency and correctness. Furthermore, the techniques allow alternative organizations and expressions to fit the needs of various users with assurance that meanings remain unchanged and that users will readily find and understand all provisions even in a new or unfamiliar standard.

NBSIR 80-2003. Lerner, N. D.; Collins, B. L. **Workplace safety symbols: Current status and research needs.** 1980 March. 62 p. Available from: NTIS; PB 81-157059.

Key words: communication; hazard; pictograms; safety; signs; standards; symbols; visual alerting; warnings.

Although written signs are a common means of conveying safety information in the workplace, pictographic symbols can be a more effective way of providing the same information. Symbols are independent of a particular written language, and can be more accurately and rapidly perceived than the comparable word message. Despite the many advantages of safety symbols, they can be ineffective or even dangerous if the intended meaning is not accurately communicated. As a result, there is a great need for careful evaluation, consistent application and eventual standardization for safety symbols.

This report documents an initial assessment of current symbol use and future requirements. It includes a review of the technical literature on symbol research; observation of safety sign and symbol use in the workplace; compilation of commercially available symbol referents; and review of national and international standards. Based upon these sources, an initial list of 40 symbol referents is presented along with research priorities for evaluating the effectiveness of symbols for these referents.

NBSIR 80-2081. Cooke, P. W. **Comparison of selected codes and standards relating to existing residential buildings.** 1980 July. 310 p. Available from: NTIS; PB 81-120842.

Key words: building rehabilitation; codes; comparative analysis; existing buildings; housing codes; maintenance; model codes; occupancy; performance levels; regulation; standards.

The performance levels of older residential buildings generally do not comply with the standards for safety or function that are required of new buildings. This report presents a comparative analysis of the specific provisions contained in seven codified documents that have been promulgated to regulate the health and safety aspects of existing residential buildings. The study examines and presents information on: (1) The extent to which codes vary among each other in establishing minimum requirements for life, health and safety in existing dwellings. (2) The differing approaches provided by traditional housing codes in contrast to more recently developed rehabilitation guideline documents regarding performance levels. (3) The degree to which each code meets its intended goals of providing and maintaining

human shelter, protection, and privacy. The code provisions are compared and analyzed in sixteen major code areas (e.g., structural requirements, light and illumination, plumbing requirements, etc.). Various inconsistencies among code documents with respect to uniformity and irrational approaches in the historical development of code provisions are indicated.

NBSIR 80-2088. Lerner, N. D.; Collins, B. L. **The assessment of safety symbol understandability by different testing methods.** 1980 August. 60 p. Available from: NTIS; PB 81-185647.

Key words: communication; evaluation method; fire-safety; hazard warnings; meaningfulness; method; pictogram; response; symbol; understandability.

This paper reports an experiment on the understandability of pictorial symbols proposed for fire-safety alerting. The experiment was designed to determine the understandability of specific symbols and to assess the effects of variations in both presentation and response methods.

The symbols were presented as slides, booklets, or placards. Subjects indicated their understanding of each symbol's meaning either by writing down a brief definition or by selecting the correct answer from among four alternatives. For both methods, subjects rated their confidence in the correctness of the answers. In the second phase of the experiment, subjects were given fifteen different messages, and asked to draw a symbol for each idea.

Mode of symbol presentation had no effect on understandability, while the use of definition and multiple choice procedures led to generally similar conclusions. The confidence ratings provided additional information about discrepancies between the two response methods.

The understandability of the 25 symbols ranged from near zero to virtually total comprehension. These data underscore the need to determine the understandability of safety symbols prior to standardizing a symbol set.

NBSIR 80-2094. Kelly, G. E.; Kuklewicz, M. E. **A laboratory study of a gas-fired condensing boiler.** 1980 November. 39 p. Available from: NTIS; PB 81-158230.

Key words: boilers; central heating; condensing boilers; efficiency, part load; fossil-fuel heating systems; gas-fired boilers; hydronic heating; pulse combustion.

As a part of the Department of Energy's energy conservation program for consumer products, the National Bureau of Standards (NBS) developed test procedures for conventional gas- and oil-fired furnaces and boilers. The Department of Energy (DoE) published their finalized version of these procedures in the Federal Register on May 10, 1978. In an effort to update and refine these test procedures, DoE directed NBS to develop a method of testing condensing furnaces and boilers which could be used to compare the annual performance of condensing and non-condensing residential heating systems. This report summarizes the laboratory tests of a gas-fired pulse-combustion condensing boiler that were carried out as a part of the development effort.

The performance of the pulse-combustion boiler was evaluated under both steady-state and part-load operating conditions. The efficiency of the unit was determined by the input/output method which measured the heat transferred to the circulating water and the energy input during each test period. Steady-state laboratory tests of the unit were conducted at constant return water temperatures of 100, 110, 120, 130 and 140 °F (37.8, 43.3, 48.9, 54.4 and 60.0 °C). Part-load performance tests were carried out at a number of these return water temperatures at on-times of approximately 5, 15, 22.5 and 42 percent.

A modified version of the heat loss procedure for estimating the seasonal performance of a residential central furnace or boiler was also used to evaluate the boiler's steady-state efficiency and part-load efficiency at a 22.5 percent on-time. A cool-down test and heat-up test were performed to obtain dynamic information which was used to calculate the unit's cyclic performance. The predicted steady-state and part-load efficiencies from the heat loss method were found to be within three percent of the performance determined using the input/output method.

NBSIR 80-2104. Kao, J. Y.; Baker, D. W. **A commentary on the instrumentation for building energy monitoring and control systems (EMCS).** 1980 September. 28 p. Available from: NTIS; PB 81-185688.

Key words: building energy monitoring; instrumentation; sensors.

This paper reviews sensors generally used for building energy monitoring and control systems (EMCS). The sensor operating principles, performances, calibration, maintenance, installation precautions, failure modes and their suitability for building EMCS use are discussed. Sensors covered in the paper include orifices, flow nozzles, Venturis, vortex shedding meters, and turbine meters for flow measurements, liquid-in-glass thermometers, resistance thermometers, and thermocouples for temperature measurements, and salt-phase transition hygrometers, impedance hygrometers, and dimensional change hygrometers for humidity measurements.

NBSIR 80-2110. Kelly, G. E.; Kuklewicz, M. E. **Recommended testing and calculation procedures for estimating the seasonal performance of residential condensing furnaces and boilers.** 1981 April. 100 p. Available from: NTIS; PB 81-197030.

Key words: annual fuel utilization efficiency; annual operating costs; central heating equipment; condensing boilers; condensing furnaces; part-load performance; rating procedure; seasonal efficiency.

Procedures are developed for testing and rating the performance of residential central furnaces and boilers of the condensing type. A condensing furnace or boiler is a unit designed to condense part of the water vapor generated by the burning of hydrogen in the fuel and equipped with a means of draining this condensate. The test procedure is similar to one developed by the National Bureau of Standards for the Department of Energy covering noncondensing central heating equipment, except that it requires slightly tighter control of the laboratory temperature, a return water temperature of 120°F (48.9°C) with a 20 degree Fahrenheit (11.1 degree Celsius) water temperature rise for hot water boilers, and offers an optional test procedure for condensing units having no off-period losses. The rating procedure provides a method for estimating the steady-state, part-load and annual fuel utilization efficiencies of condensing furnaces and boilers. It accounts for the fact that the latent heat loss for a condensing unit is smaller than for a conventional furnace or boiler, since some of the water vapor generated from burning hydrogen in the fuel is condensed and thereby gives up part of its latent heat to the heat exchanger and jacket.

NBSIR 80-2111-1. Ellingwood, B. R. **Review and refinement of ATC 3-06 tentative seismic provisions. Report of technical committee 1: Seismic risk maps.** 1980 October. 30 p. Available from: NTIS; PB 81-187551.

Key words: buildings; buildings (codes); buildings (design); earthquake; seismic risk maps; standards; structural engineering.

The Tentative Provisions for the Development of Seismic Regulations for Buildings were developed by the Applied Technology Council to present, in one comprehensive document, current state-of-knowledge pertaining to seismic engineering of buildings. The Tentative Provisions are in the process of being assessed by the building community. This report is one of a series of reports that documents the deliberations of a group of professionals jointly selected by the Building Seismic Safety Council and the National Bureau of Standards and charged with reviewing the Tentative Provisions prior to the conduct of trial designs. The report contains the recommendations and records of the committee charged with review of the seismic risk maps. The committee made 4 recommendations for revisions to the Tentative Provisions. These recommendations were made to the parent group, the Joint Committee on Review and Refinement, and their action on these recommendations is documented in a companion report.

NBSIR 80-2111-3. Salomone, L. A. **Review and refinement of ATC 3-06 tentative seismic provisions. Report of technical committee 3: Foundations.** 1980 October. 57 p. Available from: NTIS; PB 81-187569.

Key words: buildings; design; earthquakes; engineering; foundations; professional practice; provisions; soil structure interaction; standards.

The Tentative Provisions for the Development of Seismic Regulations for Buildings were developed by the Applied Technology Council to present, in one comprehensive document, current state-of-knowledge pertaining to seismic engineering of buildings. The Tentative Provisions are in the process of being assessed by the building community. This report is one of a series of reports that documents the deliberations of a group of professionals jointly selected by the Building Seismic Safety Council and the National Bureau of Standards and charged with reviewing the Tentative Provisions prior to conducting trial designs.

This report documents the activities of Technical Committee 3: Foundations. Other committee reports are similarly available. The task of Technical Committee 3 was to review and refine Chapter 6, Soil-Structure Interaction and Chapter 7, Foundation Design Requirements in the ATC report (NBS SP-510) entitled, "Tentative Provisions for the Development of Seismic Regulations for Buildings." Two meetings were held. The opening meeting of the group was on December 11, 1979, and the concluding meeting was on February 5, 1980. The minutes of these meetings and the findings/recommendations of Technical Committee 3 are presented in this report. These recommendations were made to the parent group, the Joint Committee on Review and Refinement, and their action on these recommendations is documented in a companion report.

NBSIR 80-2111-4. Marshall, R. D.; Woodward, K. **Review and refinement of ATC 3-06 tentative seismic provisions. Report of technical committee 4: Concrete.** 1980 October. 254 p. Available from: NTIS; PB 82-130915.

Key words: building; building codes; building design; earthquakes; engineering; reinforced concrete; standards; structural engineering.

The Tentative Provisions for the Development of Seismic Regulations for Buildings were developed by the Applied Technology Council to present, in one comprehensive document, current state-of-knowledge pertaining to seismic engineering of buildings. The Tentative Provisions are in the process of being assessed by the building community. This report is one of a series of reports that documents the deliberations of a group of professionals jointly selected by the Building Seismic Safety Council and the National Bureau of Standards and charged with reviewing the Tentative Provisions prior to the conduct of trial designs. The report contains the recommendations and records of the committee charged with review of the reinforced concrete design provisions. The committee made 19 recommendations for revisions to the Tentative Provisions. These recommendations were made to the parent group, the Joint Committee on Review and Refinement, and their action on these recommendations is documented in a companion report.

NBSIR 80-2111-5. Leyendecker, E. V.; Cattaneo, L. E. **Review and refinement of ATC 3-06 tentative seismic provisions. Report of technical committee 5: Masonry.** 1980 October. 349 p. Available from: the author.

Key words: building; building codes; building design; earthquakes; engineering; masonry; standards; structural engineering.

The Tentative Provisions for the Development of Seismic Regulations for Buildings were developed by the Applied Technology Council to present, in one comprehensive document, the current state of knowledge pertaining to seismic engineering of buildings. The Tentative Provisions are in the process of being assessed by the building community. This report is one of a series of reports that documents the deliberations of a group of professionals jointly selected by the Building Seismic Safety Council and the National Bureau of Standards and charged with reviewing the Tentative Provisions prior to the conduct of trial designs. The report contains the recommendations and records of the committee charged with review of the masonry design provisions. The committee made 109 ballot recommendations for revisions to the Tentative Provisions. These recommendations were made to the parent group, the Joint Committee on Review and Refinement, and their action on these recommendations is documented in a companion report.

NBSIR 80-2111-6. Lew, H. S. **Review and refinement of ATC 3-06 tentative seismic provisions. Report of technical committee 6: Steel.** 1980 October. 37 p. Available from: NTIS; PB 81-187577.

Key words: building; building codes; building design; earthquakes; engineering; standards; steel; structural engineering.

The Tentative Provisions for the Development of Seismic Regulations for Buildings were developed by the Applied Technology Council to present, in one comprehensive document, current state-of-knowledge pertaining to seismic engineering of buildings. The Tentative Provisions are in the process of being assessed by the building community. This report is one of a series of reports that documents the deliberations of a group of professionals jointly selected by the Building Seismic Safety Council and the National Bureau of Standards and charged with reviewing the Tentative Provisions prior to the conduct of trial designs. The report contains the recommendations and records of the committee charged with review of the steel design provisions. The committee made 6 recommendations for revisions to the Tentative Provisions and three additional recommendations. These recommendations were made to the parent group, the Joint Committee on Review and Refinement, and their action on these recommendations is documented in a companion report.

NBSIR 80-2111-7. Yancey, C. W. C. **Review and refinement of ATC 3-06 tentative seismic provisions. Report of technical committee 7: Wood.** 1980 October. 41 p. Available from: NTIS; PB 81-187585.

Key words: building; building codes; building design; earthquakes; engineering; standards; structural engineering; wood.

The Tentative Provisions for the Development of Seismic Regulations for Buildings were developed by the Applied Technology Council to present, in one comprehensive document, current state-of-knowledge pertaining to seismic engineering of buildings. The Tentative Provisions are in the process of being assessed by the building community. This report is one of a series of reports that documents the deliberations of a group of professionals jointly selected by the Building Seismic Safety Council and the National Bureau of Standards and charged with reviewing the Tentative Provisions prior to the conduct of trial designs. The report contains the recommendations and records of the committee charged with review of the provisions for the design and detailing of wood structures. The committee made 14 recommendations for revision to the Tentative Provisions. These recommendations were made to the parent group, the Joint Committee on Review and Refinement, and their action on these recommendations is documented in a companion report.

NBSIR 80-2111-8. Faison, T. K. **Review and refinement of ATC 3-06 tentative seismic provisions. Report of technical committee 8: Architectural, mechanical and electrical.** 1980 October. 43 p. Available from: NTIS; PB 81-187593.

Key words: architectural; electrical; elevators; mechanical; seismic coefficients.

The Tentative Provisions for the Development of Seismic Regulations for Buildings were developed by the Applied Technology Council to present, in one comprehensive document, current state-of-knowledge pertaining to seismic engineering of

buildings. The Tentative Provisions are in the process of being assessed by the building community. This report is one of a series of reports that document the deliberations of a group of professionals jointly selected by the Building Seismic Safety Council and the National Bureau of Standards and charged with reviewing the Tentative Provisions prior to the conduct of trial designs. The report contains recommendations and records of the committee charged with the review of the material related to architectural, mechanical and electrical provisions. The committee made seven general recommendations for revision and one recommendation for the addition of a new section on elevator design requirements. These recommendations by Committee 8 were made to the parent group, the Joint Committee on Review and Refinement, and their action on these recommendations is documented in a companion report.

NBSIR 80-2111-11. Leyendecker, E. V.; Harris, J. R., eds. **Review and refinement of ATC 3-06 tentative seismic provisions. Report of joint committee on review and refinement.** 1980 October. 334 p. Available from: the author.

Key words: building; building codes; building design; earthquakes; engineering; standards; structural engineering.

The Tentative Provisions for the Development of Seismic Regulations for Buildings were developed by the Applied Technology Council to present, in one comprehensive document, current state-of-knowledge pertaining to seismic engineering of buildings. The Tentative Provisions are in the process of being assessed by the building community. This report is one of a series of reports that documents the deliberations of a group of professionals jointly selected by the Building Seismic Safety Council and the National Bureau of Standards and charged with reviewing the Tentative Provisions prior to the conduct of trial designs. The group is divided into nine technical committees, each of which focused on a particular portion of the Tentative Provisions. The nine committees proposed recommendations for change to the parent group, the Joint Committee, through a Coordinating Committee. The Coordinating Committee made some modifications to the technical committees' recommendations to ensure consistency among the recommendations. This report documents the actions of the Joint Committee on the 198 recommendations for change that were presented to it. The first part of the report is a summary of the results, and the appendices contain the full documentation for each recommended change. The actions of each of the nine technical committees is documented in a separate report.

NBSIR 80-2122. Campbell, P. G.; Sleater, G. A.; Post, M. A. **Development of guide specifications for the 1980 exterior restoration of the White House.** 1980 October. 129 p. Available from: NTIS; PB 81-164535.

Key words: coatings; exterior restoration; field tests; guide specifications; laboratory tests; paint removal methods; White House.

At the request of the National Park Service, a study was performed to develop guide specifications for use in the 1980 exterior restoration of the White House. The study included: 1) an evaluation of historic practices and difficulties from painting of the White House, 2) an evaluation of technical literature on surface cleaning procedures and coating systems, 3) laboratory tests of selected coatings and field tests of selected surface cleaning procedures and coatings and 4) development of guide specifications. Four coating materials were selected for evaluation in laboratory and field tests and four surface cleaning methods were evaluated in a field test at the White House, of which one system was recommended for use in the 1980 restoration.

This report presents the findings of the study and includes the proposed guide specifications.

NBSIR 80-2136. Chang, Y. M. L.; Grot, R. A. **Energy consumption and usage characteristics from field measurements of residential dishwashers, clothes washers and clothes dryers.** 1980 October. 35 p. Available from: NTIS; PB 81-179160.

Key words: clothes dryer usage characteristics; clothes washer usage characteristic; data profiles; dishwasher usage characteristic; energy consumption; field measurements; usage patterns; water consumption.

The measured energy consumption and usage characteristics for household dishwashers, clothes washers, and clothes dryers for ten townhouses at Twin Rivers, N.J., are presented. Whenever the dishwashers and/or clothes washers were in use, the energy consumption, water consumption, frequency of usage, and water temperature were measured by a data acquisition system. The energy requirement for heating hot water could be established from the water heater's characteristic in a previous related report (NBSIR 78-1496). The electrical energy of electric clothes dryers and the gas consumption of gas clothes dryers were measured, as well as their frequency and duration of use, and exhaust temperature. Typical household usage patterns of these major appliances are also included.

It was found that, in general, the electrical energy required to operate dishwashers and clothes washers is about one tenth of the energy consumption for heating hot water. Cold water usage is about three times the hot water usage for each load of laundry. The energy loss from a pilot light burner of a gas dryer is about 50 percent of the total gas consumption of that dryer. As far as habits are concerned, the average family utilizes the dishwasher every other day and the laundry about five loads a week.

NBSIR 80-2147. Treado, S.; Kusuda, T. **Daylighting, window management systems, and lighting controls.** 1980 December. 80 p. Available from: NTIS; PB 81-152886.

Key words: daylight; energy conservation; fenestration design; illumination; lighting control; solar heat gain; window management.

This report investigates major factors concerning windows in buildings and their effect on visual conditions, thermal conditions, and energy requirements. Empirically obtained data are presented for daylight illumination as a function of solar radiation, sky condition, window size and orientation, and interior reflectance. The thermal and visual effects of several window management strategies are examined along with an analysis of automatic lighting controls. Daylight utilization is seen to offer great potential for minimizing lighting load in perimeter building areas, and careful determination of lighting needs and window management strategies can provide additional benefit.

NBSIR 80-2150. Thompson, B. E.; Chapman, R. E. **Productivity in residential construction: An annotated bibliography.** 1981 February. 59 p. Available from: NTIS; PB 81-163925.

Key words: building codes; building economics; construction; cost; economics; housing; productivity; regulation; renovation.

This report presents a state-of-the-art review of the technical literature related to one or more of the factors affecting productivity in residential construction. Particular emphasis is placed on identifying potential sources of variation between the level of productivity in new housing construction versus that in housing renovation. Although this report focuses on the residential sector, emphasis is also placed on topics such as construction management and cost control which perhaps more appropriately apply to the non-residential sector. The references have been categorized so that articles dealing with specific productivity and construction topics can be easily identified. The categories emphasized in this report are: general productivity/productivity measurement; construction productivity; residential rehabilitation/renovation; construction/housing costs; construction cost estimation and control; economics of construction; and building codes and regulations.

NBSIR 80-2163. Clifton, J. R.; Anderson, E. D. **Nondestructive evaluation methods for quality acceptance of hardened concrete in structures.** 1981 January. 54 p. Available from: NTIS; PB 81-159618.

Key words: concrete; construction; nondestructive evaluation; quality assurance; steel reinforcing bars; test methods.

Nondestructive test methods which can be used in quality acceptance programs for hardened concrete have been critically reviewed and are described in this report. Methods have been identified which provide information on the strength, quality and uniformity, thickness, air content, stiffness, finish, density of concrete as well as the location and condition of steel reinforcement. Both commonly used methods and possible test methods are covered. In addition, the feasibility of combining two or more test methods for improving the prediction of the strength or quality of concrete is explored.

NBSIR 80-2171. Lerchen, F. H.; Pielert, J. H.; Faison, T. K. **Selected methods for condition assessment of structural, HVAC, plumbing and electrical systems in existing buildings.** 1980 December. 111 p. Available from: NTIS; PB 81-186918.

Key words: building rehabilitation; concrete; electrical; evaluation; HVAC; masonry; plumbing; steel; structural systems; test methods; wood.

This report was developed with the intent of assisting government officials, designers, builders, code officials, and others involved with making technical decisions relative to building rehabilitation to evaluate the condition of existing buildings.

The report describes evaluation methods available specifically for use with the structural materials of concrete, steel, masonry, and wood, as well as, for use with the supportive systems of heating/ventilating/air conditioning, plumbing, and electrical. Both commonly used methods and other possible (but more technically complex) laboratory methods are described for the reader. Comparative tables are provided, where possible, to aid the reader in making a quick selection of the evaluation method most appropriate for the particular parameter to be tested. Considerably more information is included in the area of structural systems than in the rest of the report because of the fact that this report supplements a previous effort to develop a technical manual on structural strength for rehabilitation of existing buildings.

NBSIR 80-2174. Margulis, S. T. **Building accessibility in relation to door hardware, door users, and door use.** 1981 January. 54 p. Available from: NTIS; PB 81-159626.

Key words: architectural barriers; building accessibility; codes and standards; disability; door closers; door openers; doors; ergonomics; functional capacity; handicap; locks.

This report reviews the technical literature related to doors as architectural barriers. It examines the concept of disability and the associated concepts of impairment and handicap. It is concluded that these terms lack consensus of meaning. The concept of functional capacity is recommended as an alternative because of the more direct linkage between capacity and performance. A review of the conceptual literature on fuctional capacity and its measurement leads to the conclusion that functional capacities relevant to building accessibility generally have been identified, but more precise specifications and improved ergonomic procedures for testing capacities of the disabled are required. Furthermore, a distinction is drawn between functional capacity and door use patterns. The latter refers to how capacities are applied during actual door use. Last, door systems are examined, particularly locking and latching mechanisms, door openers and door closers. The existing literature on these raises questions about the adequacy of current accessibility codes and standards with regard to these components. Based on unresolved problems and current needs, research addressing accessibility relevant objectives is recommended.

NBSIR 80-2184. Barnett, J. P. **Energy analysis of a prototype single-family detached residence: The effects of climate, house size, orientation, internal heat release, and natural cooling.** 1981 January. 46 p. Available from: NTIS; PB 81-166514.

Key words: building design; building energy performance standards; computer simulation of house energy requirements; degree days; energy analysis; single-family detached residence.

A computer study was done to determine how the annual heating and cooling requirements of a prototypical ranch-style house are affected by changes in four energy use parameters: climate (13 locations), floor area (nominal 800 ft^2, 1200 ft^2, and 1800 ft^2), orientation (north, south, and east/west), and internal heat generation (two different levels in the 1200 ft^2 house). In addition, the effects of natural cooling on the annual cooling requirement were investigated.

The results are quantified such that the effects attributable to each variation are easily identified. Also, the heating and cooling requirements of the various sized houses are correlated to degree days.

Some of the more important findings regarding the prototypical house (as simulated in this study) are: (a) annual cooling requirements/unit area decreased with increasing floor area, while (b) annual heating requirements/unit area remained relatively constant regardless of floor area; (c) rotation of a house (with windows on only two facades) significantly affected the annual energy requirements (approximate range 20–50 percent); and (e) annual cooling requirements were significantly reduced (by as much as 48 percent) by the use of natural cooling.

NBSIR 81-2195. Harris, J. R.; Leyendecker, E. V. **Draft seismic standard for Federal buildings.** 1981 January. 96 p. Available from: NTIS; PB 81-163842.

Key words: building; building design; earthquakes; engineering; Federal government; seismic safety; standards; structural engineering.

This standard has been prepared for uniform use by all Federal agencies as an adaptation of existing voluntary standards, model building codes, Federal regulations, and research reports. It is closely based on the seismic requirements of the *Uniform Building Code* (which, in turn, are based on the *Recommended Lateral Force Requirements and Commentary* published by the Structural Engineers Association of California). However, there are many instances of substantive differences from the UBC. Several important provisions, including the seismic zoning map, have been adapted from the *Tentative Provisions for the Development of Seismic Regulations for Buildings* developed by the Applied Technology Council. A number of provisions have been added to this standard that are based on the current practices and policies of various Federal agencies. Furthermore, this standard is organized considerably differently from the UBC and many provisions are phrased differently.

NBSIR 81-2199. Cattaneo, L.; Harris, J. R.; Reinhold, T. A.; Simiu, E.; Yancey, C. W. C. **Wind, earthquake, snow, and hail loads on solar collectors.** 1981 January. 97 p. Available from: NTIS; PB 81-164550.

Key words: earthquake loads; hail loads; snow loads; solar collectors; structural engineering; wind loads.

The report describes and interprets wind-tunnel, full-scale, and field studies of wind and snow loads on flat plate solar collectors, conducted under contract for the National Bureau of Standards, and uses results of these studies and other data available in the literature to develop information, guidelines, and criteria for the design of flat plate collectors subjected to the action of wind, snow, and earthquake loads. Also given in the report are data on hail loads, based on information and studies available in the literature.

NBSIR 81-2210. Winter, F. **Onsite wastewater systems—Current practices and a proposed basis for evaluation.** 1981 March. 113 p. Available from: NTIS; PB 81-211393.

Key words: onsite wastewater systems; wastewater disposal; wastewater recirculation; wastewater reuse; wastewater treatment; water conservation.

A review of onsite wastewater systems and wastewater recirculation/reuse devices based on the literature and field inspections of systems in actual settings and usage is presented. Based upon the observations, an evaluation basis for onsite wastewater systems is proposed. Criteria and requirements for conducting and monitoring demonstration projects is presented. Wastewater systems identified as potentials for demonstration projects are suggested. Topics requiring further study are identified and recommended for specific research.

NBSIR 81-2215. Yokel, F. Y.; Salomone, L. A.; Chung, R. M. **Construction of housing in mine subsidence areas.** 1981 January. 53 p. Available from: NTIS; PB 81-174690.

Key words: design criteria; foundation design; geotechnical engineering; housing construction; mine subsidence; mining; settlement; structural design; structural engineering.

Criteria for site exploration, risk assessment, site development and housing construction in actual and potential mine subsidence areas are recommended. Appendix A includes guidance for subsidence profile determination and a proposed mathematical model which may aid in predicting complex subsidence patterns. Appendix B includes a commentary and proposed equations and procedures for the design of rigid and flexible foundations.

NBSIR 81-2220. Beausoliel, R. W.; Clifton, J. R.; Meese, W. J. **Effects of thermal insulations on electrical connections and outlet boxes.** 1981 April. 52 p. Available from: NTIS; PB 81-197006.

Key words: cellulose thermal insulation; corrosion of electrical outlet boxes and devices; electrical devices; humidity, thermal insulation and corrosion of electrical wiring; shock hazards; urea-formaldehyde thermal insulation.

When residential walls are retrofitted with "foamed-in" urea-formaldehyde or "blown-in" cellulose thermal insulations, the insulation may enter electrical outlet and switch boxes. The effects of these thermal insulations on the durability of electrical components were studied. These studies were carried out at 44, 75, and 96 percent relative humidities with test periods between one and twelve months.

Laboratory test methods were developed and tests performed to determine the electrical and corrosive effects of urea-formaldehyde and cellulose thermal insulation contained in electrical outlet and switch boxes. The boxes were tested in humidity-controlled closed-glass vessels at ambient temperatures. These tests were of an exploratory nature and did not cover all of the conditions that would exist in a residential wall. The testing methods are described in this report and the results are presented and interpreted.

Results indicate that these thermal insulations can cause significant corrosion of electrical components and can cause shock hazards and increased energy losses. It is concluded that these thermal insulations should be removed from electrical outlet and switch boxes.

NBSIR 81-2221. Beausoliel, R. W.; Meese, W. J. **Experimentally determined performance of some residential circuit breakers.** 1981 April. 49 p. Available from: NTIS; PB 81-197048.

Key words: branch circuits; circuit breaker; electrical fire; low ambient temperature; trip time.

Laboratory test results show that at low ambient temperatures some residential-type circuit breakers may not trip at currents up to 140 percent of rated currents. Under some environmental conditions this may lead to wiring temperatures that exceed the limitations specified in the National Electrical Code. The results also show that circuits sometimes open at the point of short circuits before circuit breakers operate. Ignition of combustibles proximate to the point of such short circuits sometimes occurs.

The results indicate the need for a more detailed study of overcurrent protection performance in the field and under laboratory conditions. Also needed are the development of more meaningful scientific/mathematical principles and models on the functional characteristics of circuit breakers.

NBSIR 81-2223. Rawie, C. C. **Estimating benefits and costs of building regulations: A step by step guide.** 1981 June. 93 p. Available from: NTIS; PB 81-217812.

Key words: benefit-cost analysis; building economics; building regulation; codes; construction regulation; economics; energy conservation codes; fire safety codes; regulation.

This is a how-to guide intended to help building officials, elected officials, builders, architects, engineers, and others determine the benefits and costs of proposed building code changes. The guide describes seven steps in the benefit-cost analysis. They are: (1) define the problem, including selecting prototype buildings to analyze; (2) estimate impacts on building-related costs, including government costs; (3) estimate impacts on building safety and performance; (4) select a method of relating benefits and costs (the recommended measure is Net Monetary Benefits together with information on physical life safety impacts); (5) estimate aggregate impacts on the code jurisdiction as a whole; (6) perform a sensitivity analysis; and (7) write up the results, being careful to present information on non-monetary as well as monetary effects. Worksheets are provided to assist in the analysis.

NBSIR 81-2231. Yonemura, G. T. **Criteria for recommending lighting levels.** 1981 March. 60 p. Available from: NTIS; PB 81-185126.

Key words: conspicuity; contrast; illumination; lighting; lighting levels; superthreshold visibility; vision.

The effect of lighting on behavior ranges from allowing simple detection of objects to creating moods and impressions. Lighting standards and recommendations for general applications should be based on the visibility (seeing) requirements where differences between individuals are minimal. Furthermore, lighting criteria or standards must evaluate the seeing process under stimulus conditions approximating those encountered in the real space. It is recommended that conspicuity, defined as: "how well the detail stands out from the background," or ease of seeing be the metric for visibility. Subjective visual response criteria cannot be universally applied where significant differences in interpretations and evaluations between individuals and/or groups of individuals occur. Instead they should be treated as design options to be applied when they are important aspects of the intended function of the space. In discussing the above issues, the paper identifies the major categories of variables included in the perception of the visual environment and organizes them logically with respect to their relationship in developing lighting criteria and standards. This analysis includes a breakdown of the visual processes into sensory and perceptual components.

NBSIR 81-2232. Masters, L. W.; Seiler, J. F.; Embree, E. J.; Roberts, W. E. **Solar energy systems—Standards for absorber materials.** 1981 January. 68 p. Available from: NTIS; PB 81-188278.

Key words: absorber materials; accelerated test methods; durability; solar energy; standards.

Absorber materials used in solar heating and cooling systems absorb energy from the sun and convert it to thermal energy. These materials must perform their intended functions both when first installed and after extended use. However, the environment in which absorber materials are exposed can cause degradation and loss of ability to function. Numerous problems with absorber materials in solar energy systems have demonstrated the need for standards to assess their performance and durability.

A study was performed to aid in the development of accelerated test methods needed for the evaluation of absorber materials and to

incorporate the methods into draft standards for consideration as consensus standards by the American Society for Testing and Materials (ASTM).

After identifying the performance requirements for absorber materials, laboratory and field studies were performed to measure performance according to the requirements. The data obtained, using twelve absorber materials, were used as the technical basis for two draft standards.

This report presents the results of the research, including the proposed draft standards.

NBSIR 81-2238. Yokel, F. Y.; Chung, R. M.; Yancey, C. W. C. **NBS studies of mobile home foundations.** 1981 March. 45 p. Available from: NTIS; PB 81-180978.

Key words: flood loads; mobile home foundations; mobile home standards; soil anchors; soil testing.

Two papers are presented which discuss the results of tests on soil anchors used to secure mobile homes and of an analytical study of wind and flood loads on soil anchors.

NBSIR 81-2239. Frohnsdorff, G.; Clifton, J. R. **Fly ashes in cements and concretes: Technical needs and opportunities.** 1981 March. 34 p. Available from: NTIS; PB 81-183428.

Key words: cement; concrete; fly ash.

Following a brief review of the nature of fly ashes and their levels of production and use in various countries, an estimate is made of the potentially achievable level of use of fly ash in cement and concrete in the United States. The estimate assumes that 20 percent of the mass of all the portland cement used in the United States could be replaced by the same mass of fly ash; it ignores possible competition from granulated blast-furnace slag as a finely-divided mineral admixture for concrete. It appears that about 16 million tonnes (18 million tons) per year of fly ash could be consumed in cement and concrete, provided there were sufficient ash of suitable quality and a general understanding of the technical requirements for satisfactory fly ash use. Present standards which affect the use of fly ashes are discussed. Steps which could be taken to improve knowledge of factors affecting fly ash performance in cement and concrete, and hence to improve standard test methods and specifications, are outlined.

NBSIR 81-2241. Petersen, S. R.; Barnes, K. A.; Kelly, G. E. **Engineering-economic analysis of improved heat pump performance for minimum standards development.** 1981 July. 67 p. Available from: NTIS; PB 82-133810.

Key words: energy efficiency standards; engineering-economic analysis; heat pump; mechanical equipment efficiency ratings; minimum efficiency standards; space cooling requirements; space heating requirements.

This report provides a methodology and seasonal performance data that could be used in the development of a reference basis for minimum efficiency standards for heat pumps that are economically justified on a life-cycle basis. Criteria for economic optimization are outlined. The methodology used to compute seasonal heating and cooling performance ratings and the annual energy savings resulting from efficiency improvements, by climate region, is detailed. The interdependence between efficiency ratings in the heating and cooling modes is explored using statistical analysis. An example of the procedure for determining maximum cost-effective efficiency levels is demonstrated for a 36,000 Btu/h heat pump.

NBSIR 81-2244. Carino, N. J. **Temperature effects on the strength-maturity relation of mortar.** 1981 March. 99 p. Available from: NTIS; PB 81-183410.

Key words: compressive strength; concrete; curing temperature; early age; final set; hydration; initial set; laboratory testing; maturity; mortar; regression analysis; strength prediction; temperature effects.

A study was performed to gain a fundamental understanding of the traditional maturity method used to predict the in-place strength of concrete. Research was undertaken to answer two questions: 1) What are the quantitative effects of curing temperature on the compressive strength-maturity relation of concrete? 2) Is there an age beyond which temperature no longer affects the strength-maturity relation of concrete? To simplify testing, mortar cubes were used as specimens for compressive strength determinations. Penetration resistance measurements were performed to determine initial and final setting times. Phase I of the research addressed the first question and involved preparing and curing specimens at 5°, 12°, 23°, 32° and 43°C. Phase II addressed the second question and involved curing specimens at 5° and 32°C for short periods, followed by additional curing at 23°C. It was found that initial set occurred at approximately the same maturity regardless of the curing temperature. A three-parameter hyperbolic equation was used to represent the strength-maturity relation. The parameters, determined by regression analysis, were found to vary systematically with curing temperature. Theoretical justification for the hyperbolic equation is presented and a key assumption in the maturity method is identified. The strength versus age data were also analyzed and a new concept, effective age, is suggested as a possible alternative for representing the combined effects of time and temperature on the compressive strength development of concrete.

NBSIR 81-2245. Adler, S. C.; Pierman, B. C. **Building accessibility for the disabled: A review of research needs.** 1981 March. 46 p. Available from: NTIS; PB 81-184954.

Key words: accessibility; building accessibility; building research; fire safety; handicapped; life safety.

This report traces the evaluation of public policy on accessible environments; discusses the need for development of a research basis for the design of accessible buildings including accessibility standards for both new and existing buildings, summarizes the results and research recommendations of both the Conference on Fire Safety for the Handicapped held at NBS on November 26-29, 1979 and the joint ATBCB/NBS Conference on Accessibility Guidelines held in Bethesda, Maryland on October 31-November 1, 1979, and presents an overview of current NBS accessibility research plans.

NBSIR 81-2248. Ruegg, R. T.; Chapman, R. E. **A regional economic assessment of selected window systems.** 1981 July. 125 p. Available from: NTIS; PB 81-243255.

Key words: building economics; daylighting; energy conservation; engineering economics; life-cycle costs; passive solar; regional analysis; thermal efficiency; windows.

This study, the fifth in a series of reports from the National Bureau of Standards interdisciplinary project on windows, provides guidance in selecting and using windows in buildings for greater cost effectiveness. It presents the life-cycle costs of selected window systems used in a room of a representative residence and in an office module of a representative commercial office building for nine cities in the United States, representing five heating zones and four cooling zones. The cities covered are Miami, Florida; Atlanta, Georgia; Washington, D.C.; Portland, Maine; Indianapolis, Indiana; San Antonio, Texas; Los Angeles, California; Bismarck, North Dakota; and Seattle, Washington. The results of the regional analyses are summarized, and the implications of these results are considered, both for selecting windows in new buildings and for managing windows in existing buildings. The emphasis of this report is on conveying the research findings to builders, designers, and building owners and operators—those involved immediately with the building process. The research method is described in an earlier companion report, *Economic Evaluation of Windows in Buildings: Methodology*, NBS BSS 119.

NBSIR 81-2249. Mahajan, B. M. **Unsteady water depth measurement in a partially filled 7.6 cm diameter horizontal pipe.** 1981 April. 55 p. Available from: NTIS; PB 81-203416.

Key words: diameter; drain; flow; history; horizontal; length; partially-filled; pipe; slope; stream-depth; unsteady; volume; water.

A research program to investigate the wastewater solid transport in horizontal drains is under way. The objective of the program is to develop data base and establish correlations for selecting drain pipe diameter, length, and slope for an effective solid waste transport with reduced water usage.

The purposes of this portion of the research program, which is presented here, were: (1) to measure the stream depth histories of unsteady, non-uniform transient, partially-filled pipe flow that ensues when water from a plumbing fixture is discharged into the drain, and (2) to examine the effects of the presence of a cylindrical solid and other relevant variables on the stream depth. The variables selected for the study include: the water volume discharged from the fixture into the drain, drain slope, and the diameter and length of cylindrical solids.

The report contains a description of the experimental apparatus, instrumentation and procedures, and a summary of the stream depth data acquired from experiments in a 7.6 cm diameter drain.

The depth of water stream at any given cross-section of the drain rises rapidly to a peak value and then gradually falls off to zero. The peak value of stream depth at a pipe cross-section decreases as the distance from the drain entrance increases. At a given drain cross-section, the peak value of stream depth increases with an increase in the water volume used, a decrease in the pipe slope, and with the presence of a solid in the drain. The variations in the solid diameter influence the steam depth history more than the variation in its length.

NBSIR 81-2250. Chapman, R. E.; Thompson, B. E. **Estimating area cost factors for military construction projects: A computerized approach.** 1981 May. 77 p. Available from: NTIS; PB 81-215295.

Key words: applied economics; construction; cost; estimation; location factors; model building; statistical analysis.

This report describes a computerized procedure for estimating area cost factors for military construction projects. The empirical basis for this procedure rests upon the results of an econometric analysis of over 500 military construction projects. Technical and empirical evidence from a wide variety of published sources were also used to provide supplemental information on wage rates, material prices, and the level of construction activities in the localities where the projects were undertaken. This report is intended to serve as a user manual for military personnel concerned with the problem of periodically updating the area cost factors for each service's installations. A series of technical appendices are also included which describe the theoretical underpinnings of the econometric models which constitute the core of the computerized procedure as well as provide samples of computer output and a complete listing of the computer program.

NBSIR 81-2258. Margulis, S. T. **A methodology for evaluating housing in use: A case study approach.** 1981 June. 224 p. Available from: NTIS; PB 82-104969.

Key words: dwelling units (residential); housing; Operation Breakthrough; post-occupancy housing evaluation; Project Feedback; questionnaires; research methods; survey research; user needs.

The National Bureau of Standards (NBS) has prepared a report on the methodology of Project Feedback, the evaluation of Operation Breakthrough housing in use (a post-occupancy housing evaluation). The report introduces housing evaluations and encourages their use by providing both housing questionnaires and a nontechnical, practical discussion of research methods in general and of survey research in particular. To increase the sophistication of housing evaluation research designs, the report includes a tested approach for selecting control group respondents for housing evaluations. In addition, it summarizes results of NBS's housing evaluations, principally to illustrate ways of categorizing (coding) occupants' answers, but also to introduce these studies and their results. The case study approach is meant to encourage readers to build on NBS's experiences. This book is suitable for research and instructional purposes.

NBSIR 81-2265. Hunt, B. J.; Fattal, S. G. **Review of technical information on scaffolds.** 1981 May. 103 p. Available from: NTIS; PB 81-203754.

Key words: codes and standards; construction safety; design; finite element; loads; scaffolds; stability; stiffness; strength; structural safety; work surfaces.

This report presents a review of the available literature on scaffolds and is the third of several inter-related studies of a scaffolding research program at the National Bureau of Standards (NBS). This study was sponsored by the National Institute for Occupational Safety and Health (NIOSH) to improve scaffolding system performance and reduce the work related injuries and losses.

A computerized search of the published literature was performed and technical information that could serve to upgrade existing codes and standards for scaffolds or offer direction to future analytical research has been presented. This information concerned the design, erection, operation or maintenance of scaffolding systems. Appendix A presents the 22 types of scaffolds under study. In addition, U.S. scaffold patent claims and the manufacturers' literature was reviewed and discussed. Appendix B presents selective model analyses of scaffolds.

NBSIR 81-2266. Mahajan, B. M. **Experimental investigation of transport of finite solids in a 76 mm-diameter partially-filled pipe.** 1981 April. 65 p. Available from: NTIS; PB 81-203176.

Key words: cylindrical; non-uniform; partially-filled; pitched-horizontal drain; slope; solid; velocity; volume; water.

An exploratory experimental investigation of the hydro-transport mechanisms of finite solids with non-uniform, unsteady and transient water flow introduced into a pitched-horizontal drain (p-h drain) pipe by discharging a plumbing fixture was carried out. The purpose of the investigation was to examine the effects of relevant variables on the velocity attained and the distance traversed by the solid in the p-h drain. The variables selected for the study include: the water volume used (i.e., the volume of water discharged from the plumbing fixture into the drain), diameter and length of cylindrical solid, and diameter and slope of the p-h drain.

This report contains a description of the experimental equipment and procedures, and a summary of the data acquired during the solid transport experiment in 7.6 cm diameter drain pipe at a pipe slope of 0.02, 0.04, and 0.06.

The solid dragged on a thin film of water between the solid and drain wall when relatively small water volumes ($V_w \leqslant 1.9$ liters or 0.5 gallons) were used, and the solid moved like a waterborne object when relatively large water volumes ($V_w = 3.8$ liters or 1.0 gallons) were used. The solid velocity and the distance traversed by the solid increased with an increase in the water volume used, an increase in the drain slope, a decrease in the solid diameter, and a decrease in the solid length.

NBSIR 81-2268. Lerner, N. D. **Evaluation of exit directional symbols.** 1981 May. 55 p. Available from: NTIS; PB 81-203671.

Key words: directional arrows; exit signs; fire safety; pictograms; symbols; understandability; visibility; visual alerting.

This paper discusses visibility considerations for exit symbols and the relationship between understandability and visibility concerns. Two experiments evaluated directional indicators (arrows) in the context of building exit signage. The first experiment compared the visibility of 32 arrows under degraded visual conditions that were comparable to a smoke environment. This experiment had two

objectives: (1) the development of a methodology for assessing exit pictogram visibility; and (2) a comparison of the visibilities of the specific arrows tested. A second experiment obtained subjective rankings of the arrow types on the basis of several criteria of concern for exit signage. These criteria included connotative meaning, uniqueness from other directional indicators, and appropriateness.

The visibility procedure proved to be statistically sensitive and demonstrated differences in the visibility of different arrows. An analysis of the type of confusions that occurred in errors for each arrow suggested certain relations between graphic features and errors in detection. The second experiment indicated substantial agreement between participants in ranking the arrows and revealed strong relationships between the several criteria. Together the results of the two experiments were used to evaluate the set of arrows for appropriateness for use with exit designators.

Methodological issues in evaluating symbol visibility were considered and other issues of concern in testing exit signage, such as special user groups, were also discussed.

NBSIR 81-2273. Brown, P. W.; Clifton, J. R. **Factors affecting the soundness of blended cements.** 1981 June. 26 p. Available from: NTIS; PB 82-104746.

Key words: cement; expansion; fly ash; MgO; slag; soundness; strength.

Blended cements containing fly ash and blastfurnace slag were examined to assess their soundness in the presence of admixed MgO. Measurements of linear expansion were combined with compressive strength determinations to evaluate the volume stabilities of samples cured under various conditions. The effects of magnesium silicate formation on volume stability were also examined.

NBSIR 81-2277. Kao, J. Y.; Pierce, E. T. **Control strategies for energy conservation—A case study of the Materials Building, National Bureau of Standards.** 1981 May. 47 p. Available from: NTIS; PB 81-217804.

Key words: building energy analysis; computer modeling; controls; control strategies; energy conservation for nonresidential buildings; load calculations.

The BLAST-2 Computer Program is used to investigate various heating, ventilating and air conditioning control strategies and their combinations to reduce the energy consumption of a laboratory building located at the National Bureau of Standards, Gaithersburg site. The techniques of modeling the building load and air system performance are explained. The results are presented and discussed. Control strategies investigated include dry-bulb and enthalpy economizer cycles, resetting supply air temperatures by outside temperature and zone demand, shut-down of fan systems selectively, and converting interior systems to VAV systems. By combining the various control strategies, eight percent, twenty-nine percent and eight percent of heating, cooling and fan energy respectively may be saved.

NBSIR 81-2289. Lerchen, F. H.; Pielert, J. H.; Chen, P. T. **Preliminary guidelines for condition assessment of buildings being considered for solar retrofit.** 1981 July. 140 p. Available from: NTIS; PB 82-113259.

Key words: building rehabilitation; concrete; electrical; evaluation; HVAC; masonry; plumbing; solar; steel; structural systems; test methods; wood.

This report was developed to help Federal agencies determine if buildings in their inventory are suitable for solar energy retrofit. It describes evaluation methods which are available to the facilities engineer to assist in determining whether the building and its systems (structural, HVAC, plumbing, and electrical) can be retrofitted with solar energy equipment under the Solar Federal Buildings Program (SFBP). Techniques for preliminary on-site inspection are emphasized, while more detailed evaluation techniques are described briefly and are referenced further.

The report describes evaluation methods available specifically for use with the structural materials of concrete, steel, masonry, and wood, as well as for use with the heating/ventilating/air conditioning, plumbing, and electrical supportive systems.

Comparative tables are provided for each building material to aid the reader in making a quick selection of the evaluation method most appropriate for the parameter to be tested. In addition, checklists are provided which identify common problems associated with each building material, possible causes of the problem, and the potential impact of the problem on the existing building systems and the solar retrofit system.

NBSIR 81-2290. Swaffield, J. A. **Entry transition water surface profile prediction in supercritical partially filled pipe flow.** 1981 June. 107 p. Available from: the author.

Key words: building drainage; supercritical flow; transition length; vertical stack drain entry.

The criteria governing the development of steady partially filled supercritical pipe flow are presented together with the necessary techniques to determine the water surface profile in the pipe entry transition length.

The establishment of full bore flow is predicted for a range of flow rates and pipe design parameters. Based on the water surface profile calculation technique, pipe length predictions are presented to avoid the air pressure fluctuations in the drainage system that result from full bore flow establishment.

Tabular data is presented to allow design decisions to be made that link pipe slope, diameter and roughness to the need to avoid full bore flow. A graphical technique is also presented that removes the necessity to interpolate from the tabular data.

The effect of entry geometry loss coefficients is included in the techniques presented.

NBSIR 81-2296. Winter, F.; Galowin, L. S. **Criteria and evaluation for two-step flush devices for water closets.** 1981 June. 93 p. Available from: NTIS; PB 81-226839.

Key words: dual flush toilets; low flush toilets; water closets; water conservation.

Laboratory tests of two-step flush control devices for water closets were conducted to provide data and develop test methods for evaluating water saving devices for water closets. Criteria for performance and testing procedures for laboratory testing are recommended for evaluating two-step flush devices for installation in conventional water closets.

NBSIR 81-2300. McCabe, M. E.; Ducas, W.; Orloski, M. J.; Decorte, K. N. **Passive/hybrid solar components—An approach to standard thermal test methods.** 1981 July. 86 p. Available from: NTIS; PB 81-227886.

Key words: passive/hybrid components; solar energy; steady-state tests; thermal test procedures; transient thermal tests.

As part of a continuing program to develop standard test procedures to measure thermal performance of solar heating and cooling equipment, NBS has developed a plan and methodology that will be utilized for passive/hybrid solar components. A survey of passive solar products currently available or under development enabled the development of an interim classification system consisting of ten component classifications for purposes of thermal testing. A survey of currently available thermal test procedures was performed to assess the applicability of these test methods for passive/hybrid solar components. Existing test procedures that are useful for the Direct Gain Fenestration System classification are identified, and recommendations are made for evaluation of these laboratory-based procedures by comparison with field-based testing of components under controlled interior conditions. Recommendations are also made for the development of new test procedures for passive/hybrid components classifications for which existing test methods are not applicable. A proposed program to develop testing procedures for the Storage Wall Module classification is provided.

NBSIR 81-2304. Weber, S. F.; Thompson, B. E.; Lippiatt, B. C. **Economic framework for cost-effective residential water conservation decisions.** 1981 August. 65 p. Available from: NTIS; PB 81-246779.

Key words: benefits; cost-effective; costs; economic analysis; economic decision framework; energy conservation; marginal price; net present value; residential water conservation; wastewater treatment; water rate schedules; water-saving devices.

This report presents an economic framework for utilities to use in recommending water-saving devices that are cost-effective for homeowners. A variety of devices designed to save water used in water closets, showers, and indoor faucets are described in terms of their costs and benefits. The cost components considered are acquisition, installation, maintenance, and replacement costs. Benefits considered are water savings, avoidance of wastewater treatment, and energy savings in the case of reduced hot water use. A critical factor affecting the dollar value of benefits to homeowners is the price they pay for water. An analysis of water rate schedules, based on a national sample of 90 water utilities, indicates that homeowners' actual benefits from saving the last unit of water (as measured by its marginal price) are considerably lower than the average price paid for water. Thus, estimated water bill reductions will frequently be overstated if calculated on the basis of average price. The economic framework for selecting devices evaluates both mutually exclusive and compatible devices that are either modifications of existing plumbing fixtures or features of newly installed fixtures.

NBSIR 81-2307. Swaffield, J. A. **Dependence of model waste solid transport characteristics in drainage systems on solid geometry, mass and pipe system parameters.** 1981 July. 45 p. Available from: NTIS; PB 81-229247.

Key words: building drainage; waste solid transportation; water conservation; w.c. efficiency.

Test results are presented for the transport characteristics of an extensive range of geometrically similar model solids in a 100 mm diameter UPVC drain pipe. Model solids were based on commercially available sanitary towels (napkins) discharged into the pipe system via a series of U.K. standard water closet (w.c.) types.

Following a data fit analysis, relationships are presented linking solid transport characteristics to solid, pipe and w.c. parameters.

These relationships, linked to observation of installed hospital drainage systems in the U.K., will allow laboratory test methods to be utilized in predicting the effect of design changes on system performance.

NBSIR 81-2308. Swaffield, J. A. **An initial study of the application of the numerical method of characteristics to unsteady flow analysis in partially filled gravity drainage sized pipes.** 1981 July. 64 p. Available from: NTIS; PB 81-229189.

Key words: building drainage; numerical solutions for transient depth; unsteady partially-filled pipe flow; waste solid transport.

The application of the numerical method of characteristics to the solution of the differential equations defining unsteady flow in partially filled drainage system sized pipes is outlined.

The derivation of the flow equations is presented, together with the necessary boundary equation formulation to represent variable inflow, system discharge and leakage flow past a stationary deposited solid.

A computer program, written in Fortran, is included, together with typical output, that establishes the applicability of this computational method to unsteady flow analysis in gravity flow drainage systems.

Proposals for the extension of the described techniques to the prediction of solid transport and flow attenuation in long pipes are also presented.

NBSIR 81-2310. Turner, G.; Collins, B. **Pedestrian movement characteristics on building ramps.** 1981 June. 59 p. Available from: NTIS; PB 81-229163.

Key words: building circulation; building ramps; pedestrian circulation; pedestrian flow; pedestrian movement; pedestrian ramps; ramps.

Knowledge of design for effective pedestrian circulation is one of the main requirements in building planning. While an understanding of pedestrian movement characteristics on the various component parts that make up a building circulation system is the key to effective planning, one component type, the ramp, has rarely been the subject of building circulation research.

The research described in this report is the result of an investigation of pedestrian movement characteristics on four specific building ramps during two different professional athletic contests. Variables on pedestrian movement such as speed, flow, and density were studied as well as the relationships between them. In addition, counts of pedestrians by sex were made. Results were compared for the specific ramps and with previously reported data obtained for ramps, stairs, and level surfaces.

NBSIR 81-2313. Baker, D. W.; Kao, J. Y.; Didion, D. A. **Performance evaluation of a typical energy monitoring system for steam flow in buildings.** 1981 July. 63 p. Available from: NTIS; PB 81-238545.

Key words: building energy monitoring; energy measurement; steam consumption measurement; uncertainty estimate.

Some important design features and measurement techniques are discussed for determining energy rates in building systems flowing steam. Emphasis is on use of differential pressure (ΔP) type flowmeter systems where ΔP, pressure and temperature instrumentation only can receive direct calibration. The role of systematic and random type errors in measurement of building energy is discussed and an appropriate method is given for estimating the uncertainty in the energy consumed. An example calculation of uncertainty in accumulated energy used for a 1 year period is given from typical operating data for one of the NBS laboratory buildings. The uncertainty is estimated to be 3.2% for a two-meter (series) configuration and 4.3% for a single meter (high range meter) configuration.

NBSIR 81-2317. Pierce, E. T. **Energy conservation by multiple glazing on heavy masonry buildings.** 1981 June. 30 p. Available from: NTIS; PB 81-246977.

Key words: building energy analysis; energy conservation for nonresidential buildings; historic preservation and energy conservation; load calculation; masonry thermal mass; system simulation.

The BLAST-2 computer program is used to investigate multiple glazing as a means to reduce the energy consumption of two buildings of the Library of Congress in Washington, D.C. The Thomas Jefferson Building is of very heavy masonry construction, and the John Adams Building is of heavy masonry. The techniques of modeling the building load and air system performance are explained. The results are presented and discussed. Typical perimeter modules of various floors simulated with single, double, and triple glazing are faced in four compass directions. Similar results are obtained over a range of models. Application of double glazing will save up to ten percent of heating energy but not much cooling energy while maintaining present operating requirements.

NBSIR 81-2321. Peavy, B. A. **Single-room heat balance for building heat transfer.** 1981 November. 22 p. Available from: NTIS; PB 82-135609.

Key words: building heating/cooling loads; heat balance for a single room; heat transfer; radiosity shape factors.

A single-room heat balance has been developed to provide a more precise computational tool. The primary purpose for this tool is to evaluate the effects of approximations presently used in computer programs on the determination for building heating and cooling loads. Specific algorithms to be incorporated in the room heat balance

concern radiosity shape factors, temperature difference dependent convection heat transfer coefficients, simulated room mass, and an iterative methodology for solution of room temperatures.

NBSIR 81-2335. Clark, R. E. **Effects of home weatherization on occupant comfort: First report of a field study.** 1981 September. 84 p. Available from: NTIS; PB 81-245334.

Key words: Community Services Administration; field study; occupant comfort; optimal weatherization demonstration; thermal comfort; thermostat setting practices; weatherization; weatherization and thermal comfort.

This study reports preliminary examination of data testing the hypothesis that, when existing residences are treated with weatherization retrofitting measures intended primarily to save fuel, house occupants are likely to report improvement in wintertime comfort. Data were obtained through questionnaire-guided interviews with individuals in 108 experimental houses and 37 control houses. These houses, at nine sites representing a range of U.S. climates, were part of a three-year National Weatherization Demonstration, sponsored by the Community Services Administration and planned and managed by researchers at the Center for Building Technology of the National Bureau of Standards. The experimental houses had been weatherized to determine how much their fuel usage could be reduced by cost-effective retrofitting. The control houses had not been weatherized in the demonstration. Interview topics included: thermostat setting patterns, impressions of comparative comfort, amounts of clothing worn, and specific comfort and temperature ratings for the house as a whole and for individual rooms in the house. Preliminary examination of the data has focussed on: 1) a composite "comfort change" index, comprised of indicators derived from thermostat setting practices in unusually cold weather, impressions of change in comfort-related attributes of the indoor environment, amounts of clothing worn in winter, and comfort ratings, 2) the specific comfort ratings, and 3) the temperature ratings. The results presented offer strong indications of support for the hypothesis.

NBSIR 81-2342. Powell, J. W.; Rodgers, R. C., Jr. **FEDSOL: Program user's manual and economic optimization guide for solar Federal buildings projects.** 1981 August. 132 p. Available from: NTIS; PB 82-107012.

Key words: economic optimization; life-cycle costing; solar economics; solar energy.

This report provides a user's manual for the FEDSOL computer program and a guide for designing and sizing solar energy projects for Federal buildings. The life-cycle cost procedures implemented by the computer program and explained in the report are consistent with the Federal Rules for Life-Cycle Costing (10 CFR Part 436) as applied to solar energy projects.

The FEDSOL program determines the economically optimal size of a solar energy system for a user-specified building, location, system type, and set of economic conditions; it conducts numerous breakeven and sensitivity analyses; and it calculates measures of economic performance as required under the Federal Rules. The economic model in the program is linked with the SLR (Solar Load Ratio) design method developed at Los Alamos National Laboratory to predict the performance of active systems. The economics portion of the program can, however, be used apart from the SLR method, with performance data provided by the user. An environmental data file for 243 U.S. cities is included in the program. Highly user oriented, the FEDSOL program is intended as a design and sizing tool for use by architects, engineers, and facilities managers in developing plans for Federal solar energy projects.

NBSIR 81-2344. Walton, W. D.; Waksman, D. **Fire testing of roof-mounted solar collectors by ASTM E 108.** 1981 August. 75 p. Available from: NTIS; PB 82-117698.

Key words: fire tests; roofing fire resistance; roofing fire tests; solar collectors.

A study was undertaken to investigate the use of ASTM E 108 (NFPA 256, UL 790), Fire Tests of Roof Coverings, for testing roof-mounted solar energy collectors. The ASTM E 108 test method is commonly referenced in building codes as the procedure for determining the fire characteristics of roof coverings. To data, no data have been available regarding the influence of solar collectors on the fire characteristics of roof coverings or on collectors used as roof coverings. This study focused primarily on class C intermittent flame, spread of flame, and burning brand tests, although several class A and B burning brand tests were conducted. The collectors studied were commercially available and constructed with a broad variety of glazing, casing, and insulation materials representative of those commonly in use. The collectors were tested on sloped, asphalt shingled roofs with three types of mountings: integrally as the roof, directly on the roof covering, and on standoffs above the roof covering. Data are presented showing the results of the testing conducted. An evaluation of the testing procedures as they apply to roof-mounted solar collectors is given.

NBSIR 81-2346. Dickinson, G. W. **Energy management and control systems (EMCS)—User satisfaction study.** 1981 August. 19 p. Available from: NTIS; PB 82-103656.

Key words: building energy conservation systems; EMCS; energy management; energy monitoring and control systems; HVAC controls; reliability study.

A study of 86 energy management and control systems (EMCS) was made to determine users' satisfaction and perceived system reliability. Many EMC systems reportedly were not meeting users' expectations for energy, dollar, or manpower savings. Nearly one-third of the EMCS users in this study were not satisfied with their system's performance. Undependability of the manufacturer and proprietary hardware and software were the most common problems reported. Factors found to have no apparent effect on user satisfaction were: (1) the type of facility (with the exception of hospitals) in which the EMCS is installed, (2) which manufacturer supplied the system, and (3) whether or not the system was owned by the Federal Government.

The data suggest that EMCS maintenance training, in-house maintenance capability, and reduced dependence on the system manufacturer may help improve user satisfaction.

NBSIR 81-2347. Faison, T. K. **Field measurement of branch circuit wire temperatures.** 1981 November. 44 p. Available from: NTIS; PB 82-140252.

Key words: branch circuit; electric wire; field measurements; temperature excursions; thermal insulation.

The National Bureau of Standards (NBS), under the sponsorship of the U.S. Department of Energy (DoE), planned and conducted a program to monitor temperature excursions of residential branch circuit wiring under field conditions. This program was conducted to develop a field data base needed to determine the prevailing conditions in the field and to respond to various assertions that the encapsulation of branch circuit wiring within thermal insulation is a potential hazard. It has been demonstrated through previous laboratory investigations that buried wires, when operated continuously at rated ampacity, will exceed the thermal limit established by the National Electrical Code (NEC). Approximately 2,800 circuits in 667 residences were monitored through a volunteer program with the utilities. The results of the study show that slightly more than one-third of the circuits monitored operated at or above the thermal limit established by the NEC, 60°C (140°F). Thermal distributions are shown for variables such as: region, season, and age.

NBSIR 81-2353. Peavy, B. A. **Documentation of program for determination of conduction transfer functions.** 1981 November. 49 p. Available from: NTIS; PB 82-136284.

Key words: conduction heat transfer; conduction transfer functions; initialization of heat transfer problem; parallel heat flow; response factors; thick building construction.

Conduction transfer functions are used to predict the time-dependent one-dimensional conduction heat transfer at surfaces of single-or multi-layer building constructions based on heat flux and temperature history at each surface. By the use of conduction transfer functions, heat transfer problems employing non-linear boundary conditions such as thermal radiation and time-dependent changes in the surface film resistances can be solved.

Because conduction transfer functions are analytically derived with an initial time condition of zero temperature potential throughout the solid materials, it becomes necessary to initialize the computation by including exposure to a number of outdoor weather cycles such that satisfactory initial conditions of temperature and heat flux exist at the inside and outside surfaces.

The program is set up for the use of 1-, 2-, or 3-hour time intervals, depending on the thickness of the building construction. The program allows for the combination of two building constructions, e.g., the parallel heat flow paths found in wood-frame walls.

NBSIR 81-2358. May, W. B., Jr. **Analysis of data from the energy monitoring and control system at the Norris Cotton Federal Office Building.** 1981 November. 98 p. Available from: NTIS; PB 82-138744.

Key words: building envelope; building performance data; computer data acquisition; energy conservation in commercial buildings; energy monitoring and control systems; mechanical systems.

The Norris Cotton Federal Office Building (NCFOB) in Manchester, New Hampshire, is a medium-size office building, occupied in September 1976, designed to serve as a demonstration and a feasibility test for energy-conserving building features. A building energy monitoring and control system was operated as a data acquisition system over a 13-month period ending in September 1980. Experience encountered during the checkout and operation of the system is discussed. Results from data reduction procedures used to calculate approximately 160 parameters describing the energy performance of the building are presented on a monthly basis. Hourly data are also presented for daily building operation profiles, building envelope performance, and performance of the mechanical systems.

NBSIR 81-2361. Ventre, F. T.; Stahl, F. I.; Turner, G. E. **Crowd ingress to places of assembly: Summary and proceedings of an experts' workshop.** 1981 September. 147 p. Available from: NTIS; PB 82-138199.

Key words: auditorium; building standards; crowd ingress; design procedures; evaluation procedures; facility design; facility management; public assembly; public safety; stadiums.

The movement of large crowds into places of assembly has resulted in death and injury to facility patrons and staff. Facility designers and managers seeking guidance have found little relevant information in the technical literatures of architectural and crowd control. The Law Enforcement Assistance Administration and the National Bureau of Standards convened the most knowledgeable persons in North America in the topic of crowd ingress to places of assembly to: identify best current design practices; identify best current facilities management practices; and define research needed to support improved practices in design and management. The report documents the design and management practices suggested by the assembled experts, reports related activities of the International Association of Auditorium Managers and suggests a program of research leading to improved quantitative design and evaluation procedures for crowd ingress.

NBSIR 81-2366. Weber, S. F.; Rudder, F. F., Jr.; Boehm, M. J. **Method for assessing costs of noise control requirements in multifamily residential and educational buildings.** 1981 December. 119 p. Available from: NTIS; PB 82-140047.

Key words: acoustical design; acoustics; architectural design; building codes; building economics; construction costs; cost minimization; economic impact; economics; energy; model code; noise control.

This report presents a methodology developed to measure the cost impacts of acoustical performance requirements for new buildings. The methodology can be applied to a wide range of noise control requirements. The cost items addressed by this methodology are expected changes in construction costs, the cost of acoustical testing to certify levels of performance, code administration costs, and energy savings due to modifications of the building envelope. The building components considered, which are those most commonly affected by noise control requirements, are doors, windows, interior walls, exterior walls, and floor/ceiling assemblies. The basic cost assessment method consists of linear cost estimation equations for most component designs commonly used in educational and multifamily residential buildings. Each equation relates the acoustical performance of the design to its construction cost so that construction costs associated with alternate levels of acoustical performance can be compared. The methodology also includes a cost minimization model useful for selecting the least-cost design for a particular level of acoustical performance.

NBSIR 81-2367. Swaffield, J. A. **Prediction of the hydraulic jump location following a change of slope in a partially filled drainage pipe.** 1981 November. 189 p. Available from: NTIS; PB 82-142134.

Key words: building drainage; gradually varied flow; hydraulic jump; partially filled pipe flow.

The criteria governing the formation of a hydraulic jump in a partially filled fluid conduit downstream of a slope change are presented together with the necessary techniques to enable water surface profiles and jump location to be predicted.

Computer programs designed to model the conditions leading to jump formation under flow and channel scale conditions compatible with current drainage system design are presented.

The results of a wide range of test conditions in terms of jump formation and position downstream of a change in channel slope are presented together with a set of criteria to be used in evaluating whether a jump will occur for a given set of design conditions.

NBSIR 81-2374. Lew, H. S.; Carino, N. J.; Fattal, S. G.; Batts, M. E. **Investigation of construction failure of Harbour Cay condominum in Cocoa Beach, Florida.** 1981 September. 138 p. Available from: NTIS; PB 82-117409.

Key words: building; collapse; concrete; concrete strength; construction; failure; flat plate; shear; strength.

The investigation of the collapse of a five-story reinforced concrete flat-plate structure under construction at Cocoa Beach, Florida is presented in this report. The investigation included onsite inspection, laboratory tests and analytical studies.

Based on the results of this investigation, it is concluded that the most probable cause of the failure was insufficient punching shear capacity in the fifth-floor slab to resist the applied construction loads.

Two factors contributed to the low punching shear capacity: one in the design and the other in the construction of the building. In the design, the omission of a check for punching shear resulted in a smaller slab thickness than needed to satisfy the Code requirements. In construction, the use of specified chairs having insufficient height to support the top reinforcing steel resulted in more than the cover specified in the structural drawings. Both factors contributed to reducing the effective depth of the slab such that it had insufficient strength to resist the construction loads.

The analysis showed that shear stresses in the slab at many column locations on the fifth floor exceeded the nominal shear strength. Thus, punching shear failure at one of the columns precipitated a progressive failure of the slab throughout the entire fifth floor. Collapse of the fifth floor, in turn, caused the successive collapse of the lower floor slabs. The failure of the fifth floor slab most likely initiated at column G-2, an interior column which supported the last bay of freshly placed roof concrete prior to the collapse.

NBSIR 81-2377. Yaniv, S. L.; Bauer, J. W.; Flynn, D. R.; Danner, W. F. **Effects of time-varying noise on annoyance: A review.** 1981 October. 63 p. Available from: NTIS; PB 82-133513.

Key words: duration; general adverse effect of noise; intermittency; loudness; noise criteria; time-varying noise.

This report summarizes the literature dealing with the adverse response of people to time-varying noise, and identifies both the acoustical and nonacoustical factors that influence the relationship between time-varying noise and annoyance. An examination of the laboratory research concerned with the functional relationship between annoyance and the temporal and acoustic parameters of noise shows the tenuousness of such relationships. The adequacy of currently used and/or proposed rating procedures for predicting subjective response to time-varying noise is examined. Critical gaps in current knowledge are identified.

NBSIR 81-2378. Kusuda, T. **Heat transfer analysis of underground heat and chilled-water distribution systems.** 1981 November. 63 p. Available from: NTIS; PB 82-136235.

Key words: computer program; earth temperature; heat transfer; pipes; thermal insulation; thermal properties; underground systems.

Simplified calculation procedures for determining heat exchange between the earth and a multiplicity of buried pipes having different temperature and thermal insulation are presented. The procedures deal with cases where pipes are buried side by side, as well as those when several pipes are bundled in a conduit. The effects of seasonal variation of earth temperature are treated in a quasi-steady-state equation that includes the soil thermal properties, depth of burial, pipe sizes, and relative locations of pipes. Sample calculations are included, together with the Fortran program listing and thermal properties of earth to be used for the calculations.

NBSIR 81-2381. Rossiter, W. J., Jr.; Shipp, W. E. **Solar industrial process heat systems—An assessment of standards for materials and components.** 1981 September. 97 p. Available from: NTIS; PB 82-133703.

Key words: field survey; industrial process heat; materials performance; solar collector; standards; test methods.

A study was conducted to obtain information on the performance of materials and components in operational solar industrial process heat (IPH) systems, and to provide recommendations for the development of standards including evaluative test procedures for materials and components. An assessment of the needs for standards for evaluating the long-term performance of materials and components of IPH systems was made. The assessment was based on the availability of existing standards, and information obtained from a field survey of operational systems, the literature, and discussions with individuals in the industry. Field inspections of 10 operational IPH systems were performed. The study did not address the thermal efficiencies and health and safety considerations of IPH systems.

The results of the study are presented in this report. It is concluded that standard test methods are needed for evaluating the long-term performance of materials and components used in IPH systems operating at high temperatures. Some standard test methods are available having applicability to materials and components in low temperature systems. However, in the latter case, data bases are lacking which demonstrate their applicability. Recommendations are made and priorities assigned for the development of standards for materials and components.

NBSIR 81-2390. Wu, S. T.; Clifton, J. R. **Analysis and modeling of corrosion of steel in prestressed concrete.** 1981 November. 25 p. Available from: NTIS; PB 82-141771.

Key words: concrete; corrosion; general corrosion; mathematical modeling; prestressed concrete; prestressing steel; stress corrosion.

Development of conceptual and mathematical models describing the corrosion of steel in prestressed concrete is outlined. The application of the principles of stress corrosion and general corrosion to understanding the mechanisms involved in corrosion of steel in prestressed concrete is discussed. The first step in estimating the failure time of a prestressed concrete structural system because of corrosion of the reinforced steel is to estimate corrosion rates under various but realistic conditions. A simplified approach based on mathematical modeling of concretes properties for estimating corrosion rates is proposed.

Before the proposed mathematical model can be applied to practical problems information is needed on the specific mechanisms of corrosion cell processes of steel in prestressed concrete. In addition, well designed corrosion tests need to be performed in which all the important factors affecting the corrosion rates are considered.

NBSIR 81-2397. Marshall, H. E.; Ruegg, R. T. **Recommended practice for measuring benefit/cost and savings-to-investment ratios for buildings and building systems.** 1981 November. 49 p. Available from: NTIS; PB 82-170648.

Key words: benefit-cost analysis; building economics; cost effective; economic analysis; energy conservation; investment analysis; life-cycle cost; recommended practice; savings-to-investment ratio.

This report describes how to calculate a benefit-cost ratio (B/C) and a savings-to-investment ratio (SIR) and how to use them in selecting building designs and building systems that will be cost effective in the long run. The B/C relates positive benefits, such as revenues, to project costs in the form of a ratio. The SIR, a variation of the B/C, relates project savings (i.e., cost reductions) to project costs in a ratio. It is used when there are few if any positive cash flows from a project. The B/C and SIR can be used to help answer such questions as: "Is a project cost effective?" "Which size and/or design of a project is most cost effective?" "What priorities should be given individual projects competing for a limited budget?" The report addresses different formulations of the ratios and their implications for selecting cost-effective projects.

NBSIR 81-2402. Rawie, C. C. **Estimating economic impacts of building codes.** 1981 October. 163 p. Available from: NTIS; PB 82-139551.

Key words: benefit-cost analysis; building economics; building regulation; codes; construction economics; construction regulation; economics; fire safety codes; regulation.

This report describes a method for estimating the benefits and costs of proposed changes in building codes. A companion report by the author, *Estimating Benefits and Costs of Building Regulations: A Step-by-Step Guide*, published by the National Bureau of Standards as NBSIR 81-2223, provides a simplified description of the same basic method.

This report shows the reader how to set up the problem, discount impacts to their present value, estimate code impacts on building costs, estimate effects on building safety, compute aggregate impacts, and conduct a sensitivity analysis. One chapter discusses the problem of assigning a dollar value to life safety. Worksheets and an extensive list of references, including sources of data on building costs and hazards, are included.

NBSIR 81-2404. Walton, G. N. **Calculation of inter-room air movement for multi-room building energy analysis.** 1981 November. 38 p. Available from: NTIS; PB 82-142209.

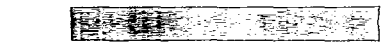
Key words: building energy analysis; computer simulation; infiltration; natural ventilation.

A model is presented for computing the infiltration and air flow between rooms of a multi-room building in terms of basic principles of fluid mechanics. This model has been incorporated into a comprehensive loads-predicting computer program. Air flows, room temperatures, and heating loads for a typical townhouse under different conditions of environment and with various construction features are computed. These calculations show the feasibility of detailed multi-room air movement analysis. They also indicate that when the inter-room openings of a low-rise structure are large compared to the envelope openings, the infiltration and total load can be accurately, and more quickly, computed by assuming no resistance to air flow between rooms. This property will also allow simplified calculations for high-rise buildings with many rooms. Methods are proposed for handling more complex air flow phenomena.

NBSIR 81-2428. Collins, B. L.; Danner, W. F.; Tibbott, R. L. **Communication systems for disabled users of buildings.** 1981 December. 73 p. Available from: NTIS; PB 82-165283.

Key words: accessibility; alarms; blind; code requirements; communication; deaf; directional indicators; handicapped users; tactile warnings.

Communication systems in buildings are designed to provide both emergency and directional information to all building users. Yet such systems, which are typically comprised of visual signs and audible alarms, may fail to reach some of the estimated twenty-seven million hearing or vision impaired people in the United States. As a result, a number of alternative communication systems have been proposed for inclusion in accessibility guidelines. In the following pages the research base underlying communication provisions for each of three sensory modalities, vision, hearing and touch, are reviewed. In addition, various proposed code recommendations are presented and discussed. The adequacy of the research base for each provision is discussed along with the need for various code provisions. It is noted that code provisions for tactile warnings and exit markings are particularly inadequate. Recommendations for further research into tactile warnings, tactile signage, and visual alarms are suggested.



GRANT/ CONTRACT REPORTS

Grant/contract reports are prepared by non-NBS persons or organizations working under a grant or contract from the National Bureau of Standards. The contract reports listed below may be ordered, using the indicated order number, directly from the National Technical Information Service (NTIS), Springfield, VA 22161, in paper or microfiche form.

NBS-GCR-80-248. Ungar, E. **Structureborne sound in buildings: Needed practical research in light of the current state of the art.** 1980 June. 55 p. Available from: NTIS; PB 81-187064.

Key words: acoustics; architectural acoustics; building acoustics; noise; noise control; sound transmission; structureborne noise.

An overview of the current state-of-the-art of structureborne sound in buildings is presented. A general introduction to the field of structureborne sound is included with a discussion of important phenomena. Summaries of recent investigations described in the technical literature are discussed relevant to excitation and local response, propagation, radiation, and control of structureborne sound in buildings. Topics for future research in structureborne sound in buildings are presented based upon this review. An annotated bibliography of recent investigations is appended.

NBS-GCR-80-249. Schultz, T. J. **Impact noise testing and rating—1980.** 1981 January. 363 p. Available from: NTIS; PB 81-158610.

Key words: acoustics; building acoustics; impact noise; noise control; noise isolation; noise rating.

A state-of-the-art review of impact noise testing and rating is presented. A historical perspective of impact noise testing and rating covers the first efforts in the 1920's through the most recent research results. The current research is discussed, with the emphasis on the development of standardized test methods and impact noise rating methods. An outline for future research needs is presented in light of the current state-of-the-art. A bibliography containing over 200 references to impact noise testing and rating is included in the report.

NBS-GCR-80-250. Sharp, B. H.; Kasper, P. K.; Montroll, M. L. **Sound transmission through building structures—Review and recommendations for research.** 1980 July. 144 p. Available from: NTIS; PB 81-187072.

Key words: acoustics; building acoustics; noise control; noise isolation; sound transmission; structure-borne noise.

This report presents a critical review of the status of technology in sound transmission through building structures, and identifies specific areas for further research. The approach taken in the review follows the steps involved in the design process, namely, prediction, measurement, and evaluation. Priorities for further research are based on the potential for achieving the following objectives: To develop new technology to reduce the cost of noise control in buildings; to increase confidence that designs will provide the required acoustical privacy; and to identify and apply sound isolation techniques that reduce energy consumption.

NBS-GCR-80-254. Thomas, W. C. **Effects of test fluid composition and flow rates on the thermal efficiency of solar collectors.** 1980 August. 91 p. Available from: NTIS; PB 81-180267.

Key words: efficiency; flow rate; heat transfer fluid; solar collector; thermal performance.

Experimental and analytical investigations were carried out to determine the significance of the heat transfer fluid and mass flow rate on the thermal performance of two liquid-heating flat-plate solar collectors. The collector thermal performance was lowered significantly for high concentrations of glycol and mineral-base oil. Heat losses measured with oil were less than the losses measured from the ASHRAE prescribed procedures.

An analytical model and procedure were used to account for variations in the test environment and fluid parameters. Calculations show that the collector flow factor (F_R) and efficiency factor (F') depend on fluid parameters while the loss coefficient (U_L) depends more strongly on fluid temperature.

NBS-GCR-80-255. Hunt, B. **Development of a research program for scaffolding standards.** 1980 August. 276 p. Available from: NTIS; PB 81-180259.

Key words: accidents; codes and standards; construction loads; construction safety; finite element; scaffold failures; scaffolding practices; scaffolds; structural analysis.

Under the auspices of the National Institute for Occupational Safety and Health (NIOSH), the Construction Safety Group of the National Bureau of Standards (NBS) has embarked on a scaffolding research program to provide the necessary technical assistance for developing performance standards and design guidelines for scaffolds. This paper describes the various problem areas that exist with construction scaffolding and appendix A presents the major types of scaffolds under study.

The first study is the analysis of scaffolding accidents and related employee casualties and is presented in appendix B. The second study is the review of current scaffolding codes and standards and is presented in appendix C. Two concurrent studies have been performed and are presented in the major portions of this paper. These are a review and evaluation of the technical literature on scaffolding and a study and analysis of in-field scaffold loading practices.

Using the results of these first four studies, this paper presents a newly developed analytically based scaffolding research plan. This plan consists of key topics of recommended research and an approach by which this plan can be implemented is demonstrated through selective modeling of scaffolding systems by a finite element analysis. Appendix D presents samples of the input and output data for the scaffold structural analysis. Final conclusions and recommendations are then presented as to the direction of future scaffolding research.

NBS-GCR-80-280. Achenbach, P. R. **Functional performance requirements for the environmental and service systems in detached housing and their impact on building energy use.** 1981 January. 168 p. Available from: NTIS; PB 81-157893.

Key words: building energy use; building service systems; energy budgets; housing research; housing standards; performance requirements; standards development.

The energy used for the environmental and service functions of space heating and cooling, domestic water heating, ventilation, lighting, and food and laundry services should all be taken into account in developing energy budgets for detached housing. The report states the functional performance requirements that should be met by these systems simultaneously with efficient energy utilization. It also identifies existing and proposed standards, guidelines, and criteria for the performance of these systems; shows how the performance criteria impact energy use; and summarizes the research needed to complete or produce consensus standards for the separate systems that can be introduced into energy performance standards for detached housing.

NBS-GCR-80-291. Ryan, P.; De Vos, D. **A survey of break-ins in two public housing sites.** 1980 November. 100 p. Available from: NTIS; PB 81-180549.

Key words: burglary; crime in public housing; household behavior patterns; housing characteristics (physical); housing security; public housing security; security hardware; victimization survey.

This report presents the findings of a baseline crime victimization survey conducted in two public housing sites. These findings are part of a test of the validity of security hardware standards developed by NBS. Included in this report is an explanation of the methodology used, demographic and behavior patterns, physical characteristics, and the crime victimization experienced at both sites. Conclusions include the observation that crime patterns indicate the usual complex variables at work and causal relationships are conjectured to be number and skill of criminals, access and exposure of entry portals, number of resident adults in the household, and quality of the building/site security system.

NBS-GCR-81-302. Shingleton, J. G.; Cassel, D. E.; Overton, R. L. **Air leakage in residential solar heating systems.** 1981 February. 206 p. Available from: NTIS; PB 81-176380.

Key words: air leakage; heat transfer; pebble-bed storage; solar collector; system efficiency; thermal performance.

A series of computer simulations was performed to evaluate the effects of component air leakage on system thermal performance for a typical residential solar heating system, located in Madison, Wisconsin. Auxiliary energy required to supplement solar energy for space heating was determined using the TRNSYS computer program, for a range of air leakage rates at the solar collector and pebble-bed storage unit. The air leakage model was based on field measurements of air flow in several residential solar air heating systems in the National Solar Demonstration Program for which leakage problems were reported. The study included the effects of heat transfer and mass transfer between the solar equipment room and the heated building, and also determined the effect of reduced air infiltration into the building due to pressurization by the solar air heating system. A simple method of estimating the effect of collector array air leakage on system thermal performance was evaluated, using the f CHART method.

NBS-GCR-81-320. Zeizel, J.; Welch, P. **Housing designed for families—A summary of research.** 1981 May. 169 p. Available from: NTIS; PB 81-214074.

Key words: children; design; environmental psychology; families; housing; interiors; lifestyle; research; site planning; sociology; standards.

Research on the social, psychological and behavioral needs of families in housing is not always easily accessible to the designers and developers of housing. *Housing Designed for Families* compiles this "user needs" information in a handbook for people involved in regulation setting, home building, and housing design. The report's format reflects the types of decisions designers must make and the basic zones that a living environment comprises. Zones are defined in terms of privacy, formality, territory, and intergroup contact.

Housing regulations set health and safety standards for new homes, but to date have incorporated little available user needs research. Because of this, today's homes, particularly those built with government assistance, are safe; but they often lack the simple amenities of design that make them truly livable.

This report documents, zone by zone, design problems as they appear in the literature. Each section includes comments on related sections of HUD's *Minimum Property Standards* (MPS) and *Manual of Acceptable Practices*. Comments make clear which sections of the two documents are responsive to the needs of tenants, which sections seem to contradict each other, and what changes might enhance the standards responsiveness to the issues raised by the research.

NBS-GCR-81-321. Carlock, J. B. III. **Use of FCHART version 3.0 to predict auxiliary energy use in residential solar energy systems.** 1981 May. 101 p. Available from: NTIS; PB 81-217010.

Key words: auxiliary energy; FCHART computer program; National Solar Demonstration Program; solar energy systems; space heating load; thermal performance.

Thermal performance predictions for five residential buildings with solar space heating and hot water systems using the FCHART computer program are compared with measured thermal performance data from each site. The FCHART calculations are based on measured meteorological data and on space heating loads that are both measured and calculated using building thermal envelope data and the modified degree day method. Because of the imprecision inherent in the load measurements, comparisons with FCHART predictions based on measured loads could only determine that seasonal predictions fall within the tolerance limits of the measured performance. Comparisons with predictions based on the degree day method indicate that the degree day method is less accurate than the FCHART method itself.

NBS-GCR-81-322. Wedekind, D. R. **Multi-family solar domestic hot water analysis.** 1981 May. 100 p. Available from: NTIS; PB 82-130139.

Key words: domestic hot water; recirculating hot water systems; solar collectors; system efficiency; thermal performance.

The National Bureau of Standards is presently reviewing the Definitive Performance Criteria for Residential Solar Heating, Cooling and Hot Water Systems. In support of that effort, this report describes a study designed to quantify the effect of daily domestic hot water loads and system design on the performance of multi-family solar domestic hot water systems.

Two multi-family solar domestic hot water systems judged representative of the systems funded by the HUD Residential Solar Demonstration Program, along with possible modifications to these systems, are modeled using the TRNSYS simulation computer program. The effects of collector array efficiency, storage capacity, and distribution heat losses were studied over a range of daily domestic hot water loads from 11 to 190 L/day-unit.

Results of simulations over representative climatic periods show that daily domestic hot water usage significantly affects solar system performance. Improved system designs are developed and modeled on an annual basis and comparison is made to system performance of the original design. Notable increases in performance can be obtained by the use of improved system configurations. Specific recommendations are made with direct emphasis on the definitive performance criteria.

NBS-GCR-81-331. Alfeld, L. E. **Research for building construction productivity—Report on the June 2, 1981 conference.** 1981 August. 26 p. Available from: NTIS; PB 81-246803.

Key words: building productivity; computer-integrated construction; conference; construction duration; productivity measurement; risks of failure; user productivity.

The conference was held to identify major research needs to improve commercial construction productivity. Productivity measures the relative values of the product of construction, the building, and the time, labor and capital used to produce, operate and maintain it. Therefore, both cost reduction and quality improvement are important in improvement of productivity. Twenty-six participants, from all sectors of the construction industry, met as a roundtable group. Five prepared papers served to stimulate wide-ranging discussion.

By the end of the day a consensus emerged around six primary research topics: 1. Develop a "family" of micro measures of construction productivity to assist individual firms in decision-making. 2. Improve macro measures of productivity to assist in understanding regional and aggregate industry trends. 3. Develop the methods needed to extend computer applications to all phases of construction decision-making. 4. Identify and develop methods to expedite the regulatory process. 5. Measure the relationships between occupant-user productivity and building design. 6. Produce the knowledge of physical properties of buildings needed to reduce risks of building failures and lower costs of designing for building safety.

Conferees further agreed that the private sector, not government, must take the initiative to formulate and conduct research. However, government should support and conduct some research.

NBS-GCR-81-332. The Rice Center. **A review of standards and common practices in building site regulation technical issues and research needs.** 1981 September. 144 p. Available from: NTIS; PB 82-117631.

Key words: building site standards; regulation; site design practices; site engineering.

Widely used design and service standards are identified for five elements of site development subject to government regulation: streets, sitework, drainage, waste water and water supply. Standards in use are found to vary widely from minimums to contradict one another. The report suggests that local custom rather than site engineering research forms the basis for development regulation. The report also found that: 1) some standards do not protect health and safety; 2) many regulations do not incorporate by reference relevant standards; and 3) not all referenced standards are technically current. The report lists areas of needed research and suggests methods for resolving conflicts among development standards.

NBS-GCR-81-333. White, E. T. **Tracing lighting design decisions for new open office space: A pilot study.** 1981 September. 196 p. Available from: NTIS; PB 82-132531.

Key words: building program; lighting design; lighting research; lighting survey.

The research activity consisted of an exploration of the design decision making process used by architects, engineers, and lighting designers for the illumination needs in open office situations. Approximately 30 firms with extensive lighting design experience comprised the sample of organizations who participated in the study. They ranged in size from large A/E and architectural companies to small lighting design and space planning offices. Personal interviews were conducted with the individual (or group) primarily responsible for making lighting design decisions. The object of the interview was to determine the criteria used (and their interrelationships) to make lighting decisions and to explore in detail how task lighting and ambient lighting requirements are established and put into practice to support necessary and desired activities. The data obtained during the interviews were used to formulate a lighting design process model, which explores the interactions among the many variables considered in lighting design. This design process model may be used as the first step in the formulation of a more generalized model which may be used for other design decisions—e.g., acoustics, thermal environment, space requirements, etc. This survey was co-sponsored by the Illuminating Engineering Society of North America (IESNA), the American Institute of Architects (AIA) and the International Association of Lighting Designers (IALD).

JOURNAL OF RESEARCH

The Journal of Research of the National Bureau of Standards reports NBS research and development in those disciplines of the physical and engineering sciences in which the Bureau is active. These include physics, chemistry, engineering, mathematics, and computer sciences. Papers cover a broad range of subjects, with major emphasis on measurement methodology, and the basic technology underlying standardization. Also included from time to time are survey articles on topics closely related to the Bureau's technical and scientific programs. As a special service each issue contains complete citations to all recent NBS publications in NBS and non-NBS media.

Mahajan, B. M.; Galowin, L. S.; Kopetka, P. A. **Models of quasi-steady and unsteady discharge from plumbing fixtures.** *J. Res. Nat. Bur. Stand. (U.S.). 86(2):* 171-179; 1981 March-April.

Key words: characteristics; discharge; drainage; flow; model; plumbing; quasi-steady; unsteady.

Modeling methods are developed to predict the discharge characteristics of simulated simplified configurations for plumbing fixtures connected to horizontal drain branch piping. Computations are carried out to illustrate several methods of determining the effect of various loss coefficients of the drain connection, pipe length, pipe diameter, and friction factor. Solutions are obtained for the case of a fixture with a constant head (continuous refill) and a falling head (emptying of a sink). Numerical solution of the non-linear differential equation for the falling head case was obtained by the Runge-Kutta method. Discharge characteristics are presented for a range of flows and pipe diameter-to-length ratios representative of plumbing installations. The feasibility of developing predictive models for hydraulic characteristics of interconnected plumbing fixture and drainage piping systems is shown. The variations of efflux rate with the drain pipe diameter, length, and slope obtained from the assumed models are similar in trend to the available experimental data.

PAPERS PUBLISHED IN NON-NBS MEDIA

Reprints from the journals listed in this section may often be obtained from the authors. Each entry has been assigned a five-digit number for NBS identification and listing purposes.

19998. Harris, J. R.; Fenves, S. J.; Wright, R. N. **New tools for standards writers,** *ASTM Stand. News* **8,** 10-16 (July 1980).

Key words: building standards; classification; decision tables; information networks; network; standards; standards-writers; systems analysis.

This paper describes rational methods intended to assist standards developers in the formulation and expression of standards. The methods provide ways to measure clarity, completeness, and consistency in the organization and content of a standard. Both guides to the organization of the text of a standard and a formal representation that can assist standards writers in determining whether their intent is correctly expressed are included. For illustrative purposes, the paper draws on a recent major application of the analysis to the Applied Technology Council's Tentative Provisions for the Development of Seismic Regulations for Buildings, and describes the experience gained through the interaction between the analysts and the team that developed the seismic provisions. Analysis of this interaction forms the basis for guidelines for the future role of analysts within the standards-writing groups.

20019. Simiu, E.; Filliben, J. J. **Weibull distributions and extreme wind speeds,** *Journal of the Structural Division* **106,** No. ST12, 2365-2374 (American Society of Civil Engineers, New York, NY, Dec. 1980).

Key words: climatology; loads (forces); probability distribution functions; reliability; statistical analysis; structural engineering; wind.

An investigation is presented into the question as to whether or not it may be assumed that the extreme wind population at various stations in the U.S. is described by probabilistic models with shorter tails than the Type I distribution. Statistical evidence, based on the comparative analysis of extreme wind data and of data generated by Monte Carlo simulation, appears to support this assumption at a large number of stations in the United States.

20029. Molino, J. A.; Zerdy, G. A.; Tremaine, S. G. **Psychoacoustic evaluation of transmission line audible noise: Building attenuation effects, methodology comparison, and field study feasibility,** *DOE/RA/29323-1,* 84 pages (U.S. Department of Energy, Office of Electric Energy Systems, Washington, DC, 1979). (Available by purchase from the National Technical Information Service, Springfield, VA 22161.)

Key words: corona noise; electric energy transmission; high voltage; human response to noise; noise pollution; psychoacoustics; transmission line audible noise.

A behavioral preference procedure and a categorical rating scale were used to assess human aversion to samples of transmission line audible noise in two separate psychoacoustic experiments. Tape recorded samples of corona noise were played back to listeners in a realistic listening room. Both outdoor and indoor listening conditions were simulated. In addition, the feasibility of conducting social surveys of the responses of residents actually living near transmission lines was briefly investigated. Conclusions were drawn that have implications for the environmental impact of high-voltage transmission lines.

20030. Molino, J. A.; Zerdy, G. A.; Lerner, N. D.; Harwood, D. L. **Preliminary tests of psychoacoustic facilities and techniques for studying the human response to transmission line audible noise,** *Energy Tech. HCP/T-6010/E2,* 70 pages (U.S. Department of Energy, Division of Electric Energy Systems, Washington, DC, Dec. 1977). (Available by purchase from the National Technical Information Service, Springfield, VA 22161.)

Key words: corona noise; environmental noise; high voltage transmission lines; human response to noise; listening room.

Progress during the first year of the DOE-NBS project on transmission line audible noise is documented. Some overall background for the project is provided. Three pilot experiments are described in which techniques to measure the human response to high-voltage transmission line audible noise are evaluated. A new, DOE-NBS "realistic" listening room facility, to be employed in future psychoacoustic experiments, is also described.

20031. Rawie, C. C. **Writing standards that meet regulatory needs,** *ASTM Stand. News* **8,** No. 9, 13-16 (Sept. 1980).

Key words: cost-benefit; economics; government regulation; safety regulation; standards.

This article urges discussion of certain issues arising from the use by regulatory agencies of standards developed by nongovernment standards-writing committees. The issues addressed are related to the technical and economic basis for nongovernment standards and documentation of such standards. Problems in these areas prevent regulatory agencies from taking full advantage of the expertise and resources that nongovernment standards-writing groups dedicate to writing standards. The aim of this paper is to promote discussion that will aid in resolving these problems and thus advance the regulatory use of nongovernment standards.

20059. Walker, G. R.; Marshall, R. D. **The development of a peak gust anemometer,** *Proc. 7th Australasian Hydraulics and Fluid Mechanics Conf., Brisbane, Queensland, Australia, Aug. 18-22, 1980,* pp. 151-154 (The Institution of Engineers, Barton, A.C.T. 2600, Australia, Oct. 1980).

Key words: anemometer; drag sphere; gust speed; instrumentation; wind sensor; wind speed.

The development and field testing of a simple drag sphere device for recording peak wind gusts are described. Also presented are the performance criteria and rationale for selecting these criteria for tropical storm applications. Based on static and dynamic calibrations as well as limited field experience, recommendations are offered for improvements in future models of the peak gust anemometer.

20078. Fanney, A. H.; Liu, S. T. **Experimental system performance and comparison with computer predictions for six solar domestic hot water systems,** (Proc. Int. Solar Energy Society Silver Jubilee Congress, Atlanta, GA, May 29-June 1, 1979), Paper in *Sun II,* K. W. Boer and B. H. Glen, eds., **1,** 972-976 (Pergamon Press, New York, NY, 1979).

Key words: computer codes—F-CHART, SOLCOST, TRNSYS; computer predictions for solar systems; NBS solar testing at Gaithersburg; solar hot water heating.

Currently three computer programs, F-CHART, SOLCOST, and TRNSYS, are being extensively utilized for the design and evaluation of solar space heating and domestic hot water systems. Although widely used, the accuracy of their predictions needs to be verified with experimental data. In order to provide data required for the validation of these computer codes for solar domestic hot water (SDHW) systems, the staff at the National Bureau of Standards has fabricated and instrumented a solar hot water test facility at its Gaithersburg, Maryland site. This paper describes the test facility, the experimental results, and compares the experimental results with the computer predictions for the first eight months of operation.

20079. Jenkins, J. P. **A comparison of test results for flat-plate water-heating solar collectors using the BSE and ASHRAE procedures,** (Proc. Int. Solar Energy Society Silver Jubilee Congress, Atlanta, GA, May 29-June 1, 1979), Paper in *Sun II,* K. W. Boer and B. H. Glen, eds., **1,** 365-369 (Pergamon Press, New York, NY, 1979).

Key words: collector efficiency; comparison German BSE vs ASHRAE 93-77 procedures; flat-plate solar collectors; German Bundesverband Solarenergie; solar collector testing; water-heating solar collectors.

The German Bundesverband Solarenergie (BSE) Working Group recently adopted and published a procedure for testing solar collectors based on thermal performance. Research facilities for testing flat-plate waterheating collectors have been built at NBS in accordance with the BSE procedure and the existing ASHRAE Standard 93-77. The purpose of this paper is to describe the BSE test procedure and compare experimental test results with those obtained using the existing ASHRAE Standard 93-77. Included is a description of the collector test facilities at NBS and the results obtained from testing five commercially available flat-plate waterheating collectors using both procedures.

20089. Siu, M. C. I. **Fibrous glass board as a standard reference material for thermal resistance measurement system,** (Proc. Symp. Thermal Insulation Performance, Tampa, FL, Oct. 23-25, 1978), *Am. Soc. Test. Mater. Spec. Tech. Publ. 718,* D. L. McElroy and R. P. Tye, eds., pp. 343-360 (1981).

Key words: calibration; fibrous glass board; guarded hot plate; heat flow meter; SRM; thermal conductivity; thermal resistance.

Results of thermal measurements on over 300 pairs of fibrous glass board specimens, and statistical analysis of the data, are presented. This material is available as a Standard Reference Material (SRM) from the Office of Standard Reference Materials, National Bureau of Standards, Washington, D.C. 20234. Considerations are discussed for effective use of this SRM in the calibration of measurement systems such as the guarded hot-plate and heat flow meter apparatuses.

20103. Fanney, A. H.; Liu, S. T. **Performance of six solar domestic hot water systems in the mid-Atlantic region,** *Proc. Conf. Solar Heating and Cooling Systems Operational Results, Colorado Springs, CO, Nov. 27-30, 1979,* pp. 25-31 (SERI/TP 245-430, DOE/Solar Energy Research Institute (SERI), Golden, CO, Nov. 1979).

Key words: energy; heat transfer; hot water; measurement; solar; testing.

In order to provide data required for the validation of computer programs for solar domestic hot water systems, the staff of the National Bureau of Standards (NBS) fabricated and instrumented six typical residential-size systems at its Gaithersburg, Maryland site. Three of the six systems utilize a single hot water tank and the other three utilize two tanks. Three different methods of freeze protection are being utilized among the systems: water-ethylene glycol mixture in the collector loop with an intermediate heat exchanger, drain-down

using solenoid valves to dump the water from the collectors, and air-heating collectors in conjunction with an air-water heat exchanger. One system relies on the thermosyphon principle while the other five require electric power for fans or pumps. The systems have been operating since June 1978. This paper describes the testing done and gives the experimental results for the first year of operation.

20121. McCabe, M. E. **A collector sizing procedure for residential solar hot water systems with prescribed thermal performance requirements,** (Proc. ASHRAE Semiannual Meet., Los Angeles, CA, Feb. 3-7, 1980), *ASHRAE Trans.* **86,** Pt. 1, 420-439 (American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., New York, NY, 1980).

Key words: f-chart; HUD initiative; performance standards; solar collectors; solar water heaters; storage tanks; thermal performance.

A graphical procedure was developed based on the f-chart design method to determine whether solar domestic water heating systems proposed for use in the HUD Hot Water Initiative Program have sufficient collector area to provide 50% of the load as prescribed by the thermal performance requirements of the Program. The procedure was specifically developed for the 11 states participating in the HUD initiative (the New-England and Mid-Atlantic States and Florida), however, it should be applicable for the sizing of the collectors for solar water heaters in other locations with similar climates. In the procedure, the collector area is first determined for a reference solar water heating system located in one of 25 locations. Area adjustment factors are then determined for a number of possible differences between the proposed system and the reference system. The required collector area is calculated as the product of the reference area and the area adjustment factors. The maximum difference in collector area calculated by the procedure and the area calculated by the f-chart computer program is less than 10%.

20147. Mahajan, B. M.; Galowin, L. S. **Water depth and solid velocity measurements in unsteady partially-filled horizontal pipe flow,** *Proc. Second Symp. Flow: Its Measurement and Control in Science and Industry, St. Louis, MO, Mar. 23-26, 1981,* pp. 649-671 (Instrument Society of America, Research Triangle Park, NC, Mar. 1981).

Key words: depth-time history; horizontal; measurements; partially-filled; pipe flow; solid; unsteady; velocity; water.

Few investigations have been reported on the transport mechanisms of finite solids in time-dependent partially-filled pipe flows. Due to increased concern for water conservation, the effects of reduced water usage on maintaining adequate transport and sweeping velocities for waterborne solids in pitched horizontal drains of gravity drainage plumbing systems has become the subject of current research. Open channel flow analogues are not applicable since they are based upon steady flow conditions. Determination of the flow characteristics for the non-uniform, transient water flow with varying depth-time history and the waterborne solids requires experimental measurement methods which do not produce any interference with the transport mechanisms. The instrumentation methods adapted and developed for these tests were: (a) electrode pins flush mounted at uniform spaced intervals on the circumference of the pipe wall at selected cross sections to determine the depth as a function of time; and (b) light photocell detectors at prescribed spacing distances along the length of the pipe to detect the passage of the solid in order to determine the velocity. The experimental apparatus, instrumentation, and procedures are described. Typical results obtained from the tests are presented to illustrate the results derived from the tests. The ability of the methods adopted are shown to be suitable to derive the empirical data base required to develop mathematical correlations applicable to pipe sizes for effective low water drainage system performance.

20148. Oonk, R. L.; Jones, D. E.; Cole-Appel, B. E. **Calculation of performance of N collectors in series from test data on a single collector,** *Sol. Energy, Tech. Note* **23,** No. 6, 535-536 (1979).

Key words: collector slope and intercept; correction factor for in-series collectors; efficiency deterioration in series arrays; performance of collectors in series; solar collector arrays.

Solar collector arrays are often arranged so that fluid flows through the collectors in a combined series and parallel fashion. Often the data supplied by a collector manufacturer is the performance for a single collector. Because it is unreasonable to expect measured test data for all possible array arrangements, a method is needed for calculating the array slope and intercept from performance data on a single collector.

This paper presents a method of extrapolating the calculation from a single collector to an array, with a correction factor CFN to predict the performance of N panels in series.

20151. Powell, J.; Ruegg, R. **Life-cycle costing of solar energy investments,** Chapter II in *Solar Design Workbook, Solar Federal Buildings Program, Sec. II Solar System Evaluation,* G. Franta, B. Glenn, S. Hogg, B. Hunn, S. Ternoey, and J. Yellott, eds., pp. 11-1-11-8 (SERI/SP-62-308, DOE/Solar Energy Research Institute (SERI), Golden, CO, Jan. 1981).

Key words: economics; Federal buildings; life-cycle costs; solar energy.

This chapter provides an overview of the life-cycle costing method of evaluating investments in solar energy. It describes the use of the method in determining the economically efficient design and size for a solar energy system, the cost effectiveness of a given system, and the establishment of project priorities.

20167. Ruegg, R. T.; Sav, G. T. **The microeconomics of solar energy,** Chapter 28 in *Solar Energy Handbook,* J. F. Kreider and F. Kreith, eds., pp. 28-1-28-42 (McGraw-Hill Book Co., New York, NY, 1981).

Key words: cost effectiveness; energy conservation; energy economics; life-cycle costing; microeconomic analysis; solar energy economics.

The purpose of this chapter is to explain and illustrate how the techniques of microeconomic analysis can be used in the design, sizing, and evaluation of solar energy systems. For the purpose of exposition, the focus is on solar hot-water and spaceheating systems for residential and commercial buildings. However, the basic concepts and procedures will generally apply to the analysis of solar energy in diverse applications, e.g., industrial process heat systems, power production, and total energy systems.

The first part of this chapter presents basic concepts and methods of economic analysis, and illustrates their use in sample problems. An overview is given of the basic steps in life-cycle cost analysis, discounting cash flows, considerations important to making assumptions, and methods of dealing with uncertainty and inflation. The second part describes the major components of costs and savings associated with solar energy systems, including various types of system costs, energy costs and savings, taxes, and government incentives. The third part describes a methodology for optimizing a solar energy system for maximum net savings. The basic concepts of optimization are set forth, and an example optimization problem is solved.

20190. Bartel, T. W. **Effect of absorber geometry on apparent absorption coefficients as measured in a reverberation chamber,** *J. Acoust. Soc. Am.* **69,** No. 4, 1065-1074 (Apr. 1981).

Key words: absorption coefficient; acoustic impedance; acoustics; architectural acoustics; building acoustics; diffraction; reverberant field; reverberation room; sound absorption.

Measurements were made in the NBS reverberation chamber to determine the apparent random incidence absorption coefficient as a function of the area, perimeter, and shape of the test specimens for three different materials arrayed as combinations of rectangular pieces. Measurements made with the specimen edges exposed and with the edges covered with reflecting material were compared. The

experimental results were compared with a theoretical model [T. D. Northwood, J. Acoust. Soc. Am. 35, 1173-1177 (1963)] using values of the acoustical admittance obtained from impedance tube measurements performed on the same materials. Both the experimental and theoretical results indicate that the random incidence absorption coefficient increases approximately linearly with E, the ratio of the perimeter to the area of the specimen for values of E ranging from 1.3 to 3.3 m^{-1}. The theoretical analysis indicates, however, that a linear extrapolation to the value $E=0$ is not necessarily valid. It was also found that if the specimen area and perimeter are kept constant, the values of the random incidence absorption coefficient decrease by a few percent as the specimen shape is changed to increase the number of vertices (inside plus outside right-angle corners) in the configuration.

20203. Molino, J. A.; Lerner, N. D.; Zerdy, G. A. **Audible noise from high-voltage transmission lines: Psychoacoustic findings,** (Proc. U.S. Department of Energy Environmental Control Symp., Washington, DC, Nov. 28-30, 1978), *Vol. 3. Solar Energy, Geothermal Energy, and Waste Heat Transmission, DOE/EV-0046,* pp. 243-255 (U.S. Department of Energy, Washington, DC, Sept. 1979).

Key words: audible noise; corona noise; extra high voltage (EHV) transmission lines.

The possible aversiveness of audible (corona) noise from extra-high voltage (EHV) transmission lines was investigated in a series of psychoacoustic experiments. Recordings of corona noise were made outdoors, generally at the edge of the property right-of-way. These recorded corona noise samples were then compared with other recorded environmental sounds, reference sounds, or spectrally-modified corona sounds, using a behavioral preference procedure. Results from three experiments, all employing the same general procedure, are presented here.

20259. Rossiter, W. J., Jr.; Mathey, R. G. **Guidelines for installation of solar components on low-sloped roofs—A summary,** *Proc. NBS/NRCA 6th Conf. on Roofing Technology, Gaithersburg, MD, Apr. 30-May 1, 1981,* pp. 58-62 (National Roofing Contractors Assoc., Oak Park, IL, Apr. 1981).

Key words: collector installation; field survey; guidelines; low-sloped roofs; roofing performance; solar collectors.

This paper presents guidelines for installation of solar collectors and related equipment on low-sloped roofs of commercial, industrial, and multi-family type buildings. The guidelines are concerned primarily with the waterproofing integrity of the roofing system, access to the collectors and roofing, attachment of different types of collector support frames and rooftop safety. Technical information from the literature, building codes, roofing field surveys, and acceptable roofing practice provided the basis for the guidelines. The guidelines include recommendations for design of the solar installation with regard to roofing performance, workmanship during collector installation, and maintenance of roofs with solar components.

20291. Streed, E. R.; Waksman, D. **Uncertainty in determining thermal performance of liquid-heating flat-plate solar collectors,** *Trans. ASME* **1103,** 126-134 (May 1981).

Key words: collector rating; measurement; solar collector; standards; thermal performance; uncertainty.

Thermal performance measurements of eight types of liquid-heating flat-plate solar collectors were conducted with two to four collectors of each type at four outdoor test sites. Tests were performed in accordance with the procedure prescribed by ASHRAE Standard 93-77. Statistical analysis of data sets for each collector type *within* test sites and *between* test sites was done using ASTM recommended methods to evaluate test method measurement uncertainty.

20293. Simiu, E.; Shaver, J. R.; Filliben, J. J. **Wind speed distributions and reliability estimates,** *J. Struct. Div. Am. Soc. Civ. Eng. Tech. Note* **107,** No. ST5, 1003-1007 (May 1981).

Key words: extreme value distributions; Rayleigh distributions; sampling errors; structural reliability; wind engineering; wind forces.

The purpose of this note is to present an investigation into the effect upon the estimation of safety levels for wind-sensitive structures of the model that describes the probabilistic behavior of the extreme wind speeds. Such an investigation is motivated by recent research results, according to which extreme wind speeds are in most cases best modeled by probability distributions with considerably shorter tails than the Type I Extreme Value distribution, in particular by the Rayleigh distribution. It is shown that safety levels estimated on the basis of the assumption that the Rayleigh distribution holds are significantly higher than those previously estimated in the literature.

20295. Simiu, E.; Filliben, J. J. **Wind direction effects on cladding and structural loads,** *Eng. Struct.* **3,** No. 3, 181-186 (July 1981).

Key words: buildings (codes); climatology; statistical analysis; structural engineering; wind engineering; wind (meteorology).

A simple procedure is proposed for estimating wind loads corresponding to various return periods, which takes into account directional information on both wind speeds and aerodynamic response. Examples of the application of the procedure are given, which show that cladding loads calculated without taking directional information on extreme wind speeds into account may in certain cases be larger than the actual loads by a factor of two or more. It is also shown that it is not appropriate, in general, to account for wind direction effects by multiplying loads determined without regard for these effects by a reduction factor of 0.8, as has been suggested in the literature. In its present form, the procedure is applicable to cladding panels and to members of relatively rigid structures in regions not subjected to hurricane winds.

20320. Kovacs, W. D. **What constitutes a turn?,** *Geotech. Test. J. Tech. Note* **3,** No. 3, 127-130 (Sept. 1981).

Key words: blow count; cathead; drilling rig; efficiency; energy; field test; in-situ test; standard penetration test (SPT).

There are wide variations in physical configuration and cathead equipment among the available drill rigs used to perform the standard penetration test. Such differences may be partly responsible for variations in blow count among different drill rigs. The paper draws attention to the fact that about half of the available drill rigs use clockwise rotation of the cathead while the others use counterclockwise rotation. Depending on which direction is used, differences in the actual number of turns could be off by as much as half a turn. This difference could result in a substantial variation in the energy delivered to the sampler and in the blow count for the same soil conditions.

20329. Harris, J. R.; Wright, R. N. **Unambiguous and complete: Applying information science to specifications,** *Construct. Specifer* **34,** No. 4, 55-62 (Apr. 1981).

Key words: buildings; classification; construction specifications; decision tables; information networks; master specification; specification; specification writers; systems analysis.

Specifications are a primary means of technical communication in the construction community. This article is concerned with improving the organization, expression and interpretation of the information contained in construction specifications. The application to construction specifications of techniques previously developed for modeling standards is described. The techniques provide an objective and rigorous representation of the meaning of a specification and allow it to be tested for aspects of clarity, completeness, and consistency. Furthermore, the techniques allow alternative organizations and expressions to fit the needs of various users with assurance that meanings remain unchanged and that users will readily find and understand all provisions even in a new or unfamiliar standard.

20361. Molino, J. A.; Zerdy, G. A.; Lerner, N. D.; Harwood, D. L. **Initial psychoacoustic experiments on the human response to transmission line audible noise, January 1, 1978 to December 31, 1978,** *DOE/ET/6010-1,* 86 pages (Available from the National Technical Information Services, Springfield, VA 22161, 1978).

Key words: aversiveness measures; corona noise; environmental noise impact; high-voltage transmission lines; human response to noise; modification of noise spectra.

A behavioral preference procedure, the "acoustic menu," was used to assess human aversion to the sounds from two samples of transmission line audible noise and from samples of other environmental noises. The audible (corona) noise produced by extra-high voltage (EHV), overhead transmission lines was tape-recorded during moist weather. Reproduced samples of corona noise, other common environmental noises, and artificial reference stimuli were compared in two experiments. The two corona noise samples were found to be equally preferred to: (1) a 1000 Hz octave band of noise about 11 db SPL higher than the corona noises and (2) a collection of other environmental noises about 8 db SPL higher than the corona noises. The corona noise samples were more aversive than the ambient sounds (including rainfall) occuring near rural transmission lines and were roughly equivalent in aversiveness to the noise from a room air conditioner (indoor recording). Knowledge of the source of the corona noise (from photographs and a brief description) did not affect its aversiveness. Of the simple frequency-weighting scales, the A-weighted sound level reduced the difference between the two corona noise samples and the set of other environmental sounds from about 8 db SPL to about 3 db SPL. The D-weighted sound level further reduced this discrepancy to about 2 db. These results were obtained with only two samples of corona noise; other samples may give different results. A third experiment evaluated the aversiveness of audible noise from EHV electric transmission lines for spectral modification of 5 different tape-recorded samples. The relative contributions of low-frequency humming and buzzing and of high-frequency hissing and crackling components of the noise proved more aversive for all five samples to a group of 25 listeners. Therefore, for outdoor or open window listening, engineering efforts should be directed at reducing the high-frequency portion of the audible noise spectrum. A fourth experiment essentially replicated the above results with a different psychophysical method.

20362. Molino, J. A.; Zerdy, G. A.; Lerner, N. D.; Harwood, D. L. **Psychoacoustic evaluation of the audible noise from EHV power lines,** (Proc. 7th IEEE/PES Transmission and Distribution Conf., Atlanta, GA, Apr. 1-7, 1979), Paper *79CH1399-5-PWR,* pp. 95-98 (Institute of Electrical and Electronics Engineers, Inc., New York, NY, 1979).

Key words: audible noise; EHV power lines; noise, audible.

A series of three psychoacoustic experiments was conducted with samples of audible (corona) noise tape recorded 15 m (50 ft) from extra-high-voltage transmission lines. Altogether 77 listeners responded to these and other sounds in a realistic listening room environment. The results showed that corona noise is more aversive than the ambient sounds (including rainfall) occuring near rural transmission lines and that knowledge of the source of the corona noise did not affect its aversiveness to the listeners. The results also showed that common acoustic measurement scales tend to underestimate the aversiveness of corona noise and that the high-frequency components of corona noise contribute most toward the aversive reactions of listeners.

20364. Hunt, C. M. **Air infiltration: A review of some existing measurement techniques and data,** (Proc. Symp. Building Air Change Rate and Infiltration Measurements, Washington, DC, Mar. 12, 1978), *Am. Soc. Test. Mater. Spec. Tech. Publ. 719, Building Air Change Rate and Infiltration Measurements,* C. M. Hunt, J. C. King, H. R. Trechsel, eds., pp. 3-24 (Oct. 1980).

Key words: air leakage measurement; infiltration review; ventilation analysis.

This paper reviews the state of the art in the measurement of ventilation and air infiltration. It considers tracer gas techniques and discusses some of the tracer gases used as well as some of the potential sources of error. It also discusses fan pressurization/evacuation procedures for measuring building tightness and compares fan and tracer measurements. It discusses the ASHRAE crack method. It also considers a number of factors influencing infiltration rates and finally reviews a few of the empirical equations which have been developed to correlate infiltration rate with wind velocity and inside-outside temperature difference.

20365. Grot, R. A. **A low-cost method for measuring air infiltration rates in a large sample of buildings,** (Proc. Symp. Building Air Change Rate and Infiltration Measurements, Washington, DC, Mar. 12, 1978), *Am. Soc. Test. Mater. Spec. Tech. Publ. 719, Building Air Change Rate and Infiltration Measurements,* C. M. Hunt, J. C. King, H. R. Trechsel, eds., pp. 50-59 (Oct. 1980).

Key words: air infiltration; air sample bags; energy conservation; retrofit; sulfur hexafluoride; tracer gas; weatherization.

A method for collecting air infiltration data in a large sample of dwellings is presented. The method consists of a tracer gas dilution technique employing air sample bags which are analyzed in a central laboratory. The method will be applied to a Community Services Administration optimal weatherization demonstration in approximately 300 dwellings at 16 sites throughout the United States. The method will yield air exchange rates under typical heating season conditions for each dwelling in the demonstration. Preliminary data on air infiltration rates in low-income housing in Portland, Maine are presented.

20386. Harris, J. R. **Information flow in the development of earthquake provisions for building codes,** *Proc. Conf. V Communicating Earthquake Hazard Reduction Information, Denver, CO, May 22-24, 1978,* pp. 288-306 (Office of Earthquake Studies, U.S. Geological Survey, Menlo Park, CA, 1978).

Key words: building codes; building regulatory system; buildings; building standards; codes, building; earthquake; seismic risk; standards, building.

This report describes how information flows through the building regulatory system and how this flow is being taken into account in the development of new building code provisions for earthquake hazards. Many sectors of the construction community play a role in the complex flow of information in and out of building codes, each with its own set of decision makers, but the local building official is the key figure. This history of earthquake provisions in building codes shows a slow evolution that is typical in the building regulatory system, partially because of the complex pattern of communication and decision making. New provisions have recently been developed for consideration by the regulatory community, but it will be several years before their path through various standards and model codes into legal building codes is complete.

20403. Harris, J. R.; Wright, R. N. **Computer aids for the organization of standards,** *Proc. Second Conf. Computing in Civil Engineering, Baltimore, MD, June 9-13, 1980,* pp. 112-121 (American Society of Civil Engineering, New York, NY, 1980).

Key words: computer database; computer program; methodology; specifications; standards.

A decade of research has produced a systematic methodology for the analysis and representation of design standards. The methodology assists in the formulation, expression, and use of standards, specifications or legal code requirements. This paper reports on research for elements of that methodology for dealing with the scope and the arrangement of standards. Functional and structural descriptions of provisions provide rational bases for classification of each requirement of a standard. The classification is used as a database for computer software that produces an index and alternative outlines for the standard. A prototype program has been developed

and implemented in FORTRAN on the UNIVAC 1108 at the National Bureau of Standards. Significant improvements over previous computer aids in the field include: flexibility in accommodating various classification schemes; the ability to generate an index based on meaningful and relevant terms; user selection from several logical criteria in the construction of outlines; the possibility of overriding the explicit logic of the classification; a routine for interactive generation of outlines that supports the creative talents of the user with the analytical and logical power of the computer. The program has been applied in recent projects to analyze and improve seismic design standards. The algorithms are being implemented in a general purpose, production-type computer aid for the analysis, formulation and expression of standards.

20430. Harris, J. R. **Snow accumulation on and around solar collectors,** *Proc. 37th Eastern Snow Conf., Peterborough, Ontario, Canada, June 5-6, 1980,* pp. 54-65 (Eastern Snow Conf., Atmospheric Environment Service, Downsview, Ontario, Canada, 1981).

Key words: building; load; roof; snow; snow load; solar collector; structural engineering.

Studies of the accumulation of snow and ice on buildings with flat plate solar collectors were carried out during the winter of 1979. Although the studies were generally qualitative, preliminary guidelines for snow load criteria were developed. Observations identified two significant phenomena: the sliding of snow from collector surfaces and the drifting of snow around protruding collectors. It was found that only those collectors which are relatively steep (more than 50° from the horizontal) and are free of obstructions will shed snow reliably. The accumulation of snow sliding from collectors appears to be a significant load for roof structures. It was also found that collectors that protrude from roofs tend to create drifts, much as a snow fence. The common installation of several parallel rows of protruding collectors creates a situation somewhat like a "sawtooth" factory building roof and requires special attention in design of the roof structure. Further study of the problem is merited.

20435. Harris, J. R.; Fenves, S. J.; Wright, R. N. **Logical analysis of tentative seismic provisions,** *J. Struc. Div. Proc. Am. Soc. Civil Eng.* **107,** No. ST8, 1629-1641 (Aug. 1981).

Key words: building; building codes; building standards; earthquake-resistant design; seismic design; systems analysis.

This paper describes a study of the format and expression of the *Tentative Provisions for the Development of Seismic Regulations for Buildings* developed by the Applied Technology Council. The methods of analysis employed provide objective measures of clarity, completeness, and consistency, and an alterative formal representation with which to examine the correctness of the provisions. The formal representation of the provisions and the findings of the analysis will assist those concerned with the future development of the provisions and their implementation within the various national standards and model codes.

20440. Metz, F. E. **Two examples of passive solar retrofit for historic structures,** (Proc. 5th Natl. Passive Solar Conf., Amherst, MA, Oct. 19-26, 1980), Extended Abstract in *Passive Solar 1980,* J. Hayes and R. Snyder, eds., **5.2,** 1305-1306 (1980).

Key words: historic; passive solar; retrofit; solar greenhouse; Trombe wall.

Passive application for existing buildings is a multi-faceted challenge. The retrofit of structures in historic districts compounds this challenge. In spite of the many problems, the greatest potential for passive/hybrid applications may be within the vast abundance of our existing buildings.

20463. Rossiter, W. J., Jr.; Weidt, J. L.; Saxler, R. J. **A field survey of the performance properties of insulation used to retrofit cavity walls of residences,** (Proc. ASHRAE/DOE-ORNL Conf. Thermal Performance of the Exterior Envelopes of Buildings, Kissimmee, FL, Dec. 3-5, 1979), *ASHRAE SP 28,* pp. 901-915 (ASHRAE, 345 E. 47th St., New York, NY, 1981).

Key words: conservation; energy; field survey; insulation; moisture content; residences; retrofit; thermal resistance.

A study was conducted to obtain information on the performance of retrofit insulations which had been installed in the sidewalls of existing residences. Most of the thirty-nine houses included in the study had wood-frame sidewall construction and were located in the mid-West, mid-Atlantic and Northeast.

The insulations represented those commonly used in the United States to retrofit side-walls of housing: urea-formaldehyde based foam, loose-fill cellulose, and loose-fill mineral fiber. With few exceptions, the insulations had been installed in the sidewalls at least 2 years prior to their examination and their ages ranged from about one and a half to ten years.

In the field phase of the study, small sections of sidewalls were opened in the late fall or early winter and the retrofit insulations were examined. Observations were made on performance factors such as: the completeness of filling the cavity, the condition of the insulation and wall components, and evidence of moisture accumulation such as water stains on sheathing, studs and other wall components.

Shrinkages of urea-formaldehyde based foams, and voids within loose-fill insulations were measured. Shrinkage was observed to have occurred for all urea-formaldehyde based foam specimens. For those seventeen cases in which the foam was not excessively cracked and the linear shrinkage was measurable, it was found to be within a range of 4 to 9 percent. For the six test houses containing loose-fill insulation which were opened at the top of the wall cavity, only one with cellulose contained a void at that location. It could not be determined whether the void was attributable to settling of the insulation or initial incomplete fill of the cavity.

In the laboratory phase of the study, insulation specimens removed from the walls of the residences were tested to determine their density, thermal resistivity and moisture content. In addition, the pH of the urea-formaldehyde based foam specimens was determined. Results of the laboratory measurements are discussed and compared with data and information obtained from other studies. Results indicated that the retrofitting of the inspected side-walls was for the most part accomplished without adverse effect upon them.

20470. Metz, F. E. **Health and safety criteria for passive solar systems,** (Proc. 5th Natl. Passive Solar Conf., Amherst, MA, Oct. 19-26, 1980), Extended Abstract in *Passive Solar 1980,* J. Hayes and R. Snyder, eds., **5.2,** 945-949 (1980).

Key words: building codes; constraints; fire safety; glazing; hazards; passive solar.

Passive solar technologies may introduce new and unusual health and safety concerns within the building environment. Conversely, existing building code requirements may present constraints to the effective use of some passive technologies. Some of the health and safety topics to be covered include: fire safety, physical hazards, air quality, and environmental health factors. The solar industry will be confronted with even more restrictive health and safety requirements as passive construction becomes more prevalent and is extended to non-residential building types. This paper will present some of these constraints and identify possible hazards.

20475. Molino, J. A. **Annoyance and noise,** Chapter 16 in *Handbook of Noise Control, Second Edition,* C. M. Harris, ed., pp. 16-1—16-9 (McGraw-Hill Book Co., New York, NY, 1979).

Key words: acoustics; annoyance; environmental noise; noise measurements; psychoacoustics; psychology.

Psychophysical data are reviewed on the annoyance caused by noise. Annoyance varies with three primary acoustic factors: sound level, frequency, and duration. In addition, several secondary acoustic factors have an effect: spectral complexity, fluctuations in sound level, fluctuations in frequency, rise-time of the noise, and localization of the noise source. Non-acoustic factors also influence annoyance due to noise. These include physiology, adaptation, past experience, present activity, predictability, perceived necessity, individual differences, and personality.

20477. Molino, J. A. **Auditory space perception,** Article in *International Encyclopedia of Psychiatry, Psychology, Psychoanalysis, and Neurology,* pp. 222-227 (Aesculapius Publ. Inc., New York, NY, 1977).

Key words: audition; auditory localization; auditory space perception; experimental psychology; hearing; psychoacoustics.

Scientific data on human auditory space perception is presented. History and theories related to physical measurements are reviewed. Current methods and empirical results in auditory localization are given. A section on physiological models and practical applications is included.

20499. Lippiatt, B. C.; Weber, S. F. **Labor and materials cost of weatherizing low-income housing,** (Proc. Natl. Conf. Optimal Weatherization, Washington, DC, Dec. 8-10, 1980), Paper in *Optimal Weatherization,* pp. 103-113 (Information Dynamics, Inc., Silver Spring, MD 20902, 1981).

Key words: building economics; data analysis; data collection; economic analysis; energy conservation; insulation; labor cost; low-income housing; materials cost; statistics; unit costs; weatherization.

This paper presents the major results of a project involving the collection and analysis of field data from 12 U.S. cities on the costs of retrofitting low-income houses for energy conservation. The energy conservation techniques presented consist of a variety of architectural weatherization options designed to reduce heat losses due either to air infiltration or conduction. This project is part of the Community Services Administration Weatherization Demonstration Program being carried out with technical assistance from the National Bureau of Standards. The methods used to collect and synthesize the data on the major cost components of installing these architectural options are described. The results include the mean unit cost of installing each option by city, and the relative importance of labor and materials costs. The results suggest that if a primary national policy goal were to create jobs in weatherization, then the infiltration options should be emphasized since they are labor-intensive than the conduction options.

20512. May, W. B., Jr.; Spielvogel, L. G. **Analysis of computer-simulated thermal performance: The Norris Cotton Federal Office Building,** (Proc. ASHRAE Semi-Annu. Meet., Chicago, IL, Jan. 25-29, 1981), *ASHRAE J.* **87,** Pt. 1, 43-50 (1981).

Key words: building models; building performance data; computer simulations, building; energy conservation in commercial buildings; heat pumps; validation of computer models, buildings.

Five computer-based simulations of the Norris Cotton Federal Office Building (NCFOB) in Manchester, New Hampshire, were performed using a state-of-the-art proprietary hour-by-hour building simulation program. Results of the simulations are compared with each other and with actual measured data at several levels of detail including total energy consumption, consumption by fuel type, and heating and cooling requirements. Good agreement between the simulation and actual data is demonstrated and consequences of design features are discussed.

20521. Kusuda, T. **A comparison of energy calculation procedures,** *ASHRAE J.* **23,** No. 8, 21-24 (Aug. 1981).

Key words: ASHRAE TC 4.7; computer analysis; energy calculation; simplified energy analysis.

ASHRAE's Technical Committee on Energy Calculations (TC 4.7) has developed a proposed simplified procedure suitable for manual or pocket calculators. The proposed simplified procedure was compared with seven detailed computer simulation energy analysis programs—AXCESS, BLAST, BLDSIM, DOE-2, E-CUBE, ESAS, and TRACE. The comparative calculations were done on a Washington, DC office building, for four typical HVAC systems. Discrepancies between the results using the seven computer simulation methods involving seven separate analysts were generally greater than the differences between the simplified method and a single computer simulation method when both were used by the same analyst. Major reasons for discrepancies between the proposed TC 4.7 simplified method and the detailed computer simulation methods are discussed, as well as the difficulties in using the simplified procedure.

20524. Simiu, E. **Modern developments in wind engineering: Part 2,** *Eng. Struct.* **3,** 242-248 (Oct. 1981).

Key words: aerodynamics; building codes; meteorology; wind engineering; wind forces; wind tunnels.

This is the second paper in a series devoted to a review of the state of the art in wind engineering. The paper presents information on wind tunnel testing for both research and design purposes. Specific topics covered include: The influence of viscosity effects upon the reliability of test results for bodies with curved shapes and with sharp edges; the extent to which atmospheric turbulence needs to be simulated in laboratory tests; the effect of turbulence scale and turbulence intensity upon aerodynamic forces; and difficulties encountered in the simulation of point and area loads.

20525. Simiu, E. **Modern developments in wind engineering: Part 1,** *Eng. Struct.* **3,** 233-241 (Oct. 1981).

Key words: atmospheric turbulence; buildings; design (structural); extreme winds; hurricanes; micrometeorology; structures; tornadoes; wind engineering; wind profiles.

The paper presents a state of the art review of material applicable to structural design, from the following areas: meteorology, micrometeorology (mean wind profiles and atmospheric turbulence characterization), and extreme wind climatology in well-behaved climates, hurricane-prone regions, and tornado-prone regions.

20538. Gujral, P. S.; Clark, R. J.; Burch, D. M. **Transient thermal response of an intermittently cooled massive building,** (Proc. ASHRAE/DOE/ORNL Conf. Thermal Performance Exterior Envelopes of Buildings, Orlando, FL, Dec. 3-5, 1979), *ASHRAE SP 28,* pp. 751-756 (American Society of Heating, Refrigeration and Air-Conditioning Engineers, New York, NY, 1981).

Key words: energy conservation; night cooling; night ventilation; thermal mass.

A single-room externally insulated masonry test house was built within the environmental chamber at the National Bureau of Standards. The structure was subjected to diurnal summer sol-air temperature cycles while two energy conservation schemes were monitored. Both schemes utilized the building thermal mass to store nighttime cooling energy; the first, through night mechanical cooling, and the second through the use of ambient air. The results indicate that mechanical cooling is effectively stored in the building mass during the night so that no additional daytime cooling is needed for even the most extreme summer conditions. The tests further indicate

that circulation of night ambient air effectively cools the structure so that no mechanical cooling is needed for summer cycles typical of many regions in the United States.

The experimental test results are compared with those obtained from an analytical model, with excellent agreement.

20539. Richtmyer, T. E.; May, W. B.; Hunt, C. M.; Hill, J. E. **Thermal performance of the Norris Cotton Federal building in Manchester, New Hampshire,** (Proc. ASHRAE/DOE/ORNL Conf. Thermal Performance Exterior Envelopes of Buildings, Orlando, FL, Dec. 3-5, 1979), *ASHRAE SP 28,* pp. 781-797 (American Society of Heating, Refrigeration and Air-Conditioning Engineers, New York, NY, 1981).

Key words: air-cooling; air leakage; energy; heat-recovery; insulation; measurement; office-building; radiant; solar; space-heating.

The Norris Cotton Federal Office Building is a medium-size 7-story government office building of approximately 11,000 m^2 (117,000 ft^2) total floor space. It is located in Manchester, New Hampshire and has been designed to demonstrate a number of energy saving concepts.

Some of the major energy conserving features of the building are the use of solar collectors; heavy masonry construction with exterior insulation; small overall window area; heat recovery from heat pumps, chillers, a natural gas-powered engine/generator, and the ventilation system; modular boilers; thermal storage tanks; and a variety of energy conserving lighting systems.

The staff of the National Bureau of Standards (NBS) has been monitoring the performance of the building since it was occupied in September, 1976. This paper will describe the building's thermal performance for the first three years of operation. The energy consumption in the building is presented and compared to the original design goal of 625 MJ/(m^2·years) (55kBtu/(ft^2·year)). The differences will be explained using the results of thermographic measurements and measurements of air exchange rates in the building along with analysis of the weather data and building operational problems that have occurred since 1976. It has been found that it is difficult to actually achieve designed-for performance in this building because its experimental mechanical system is unusually complex and its construction details are unconventional.

20540. Grot, R. A.; Clark, R. E. **Air leakage characteristics and weatherization techniques for low-income housing,** (Proc. ASHRAE/DOE/ORNL Conf. Thermal Performance Exterior Envelopes of Buildings, Orlando, FL, Dec. 3-5, 1979), *ASHRAE SP 28,* pp. 178-194 (American Society of Heating, Refrigeration and Air-Conditioning Engineers, New York, NY, 1981).

Key words: air infiltration; air sample bags; fan depressurization; low-income houses; weatherization.

Data are presented on the air leakage characteristics of approximately 250 dwellings occupied by low-income households in 14 cities, in all major climatic zones of the United States. Two types of measurements were used: a tracer-gas decay technique using air sample bags, which was developed at the National Bureau of Standards to measure natural air infiltration; and a fan depressurization test that measures induced air exchange rates. The data presented here show that for this group of dwellings natural air infiltration rates are distributed approximately lognormally.

The induced air exchange rates are a measure of the tightness of building envelopes. There is little correlation between the natural air infiltration rates and the induced air exchange rates in these dwellings, unless the buildings are divided into classes of similar buildings. The use of fan depressurization as a diagnostic tool to assist weatherization crews in tightening buildings is discussed. Preliminary estimates are presented of the reduction in induced air exchange rates that may be achieved by applying building weatherization techniques.

20541. Gillette, G. **The energy potential of daylighting in a classroom,** (Proc. ASHRAE/DOE/ORNL Conf. Thermal Performance Exterior Envelopes of Buildings, Orlando, FL, Dec. 3-5, 1979), *ASHRAE SP 28,* pp. 368-380 (American Society of Heating, Refrigeration and Air-Conditioning Engineers, New York, NY, 1981).

Key words: daylighting; energy conservation; envelope design; instructional facilities; passive solar energy; windows.

An analysis is presented where a classroom of prescribed size and occupancy has various fenestration designs applied to it and the resulting thermal and daylighting energy performance calculated. An attempt is made to relate the heating/cooling requirements of a window opening with its potential as a source of natural light. The parameters glass area, glass type (double-pane, reflective, etc.), and ceiling height are evaluated for a classroom in Ann Arbor, Michigan operated over the course of a 9-month school year. Comparisons are made between the performance of a design based on ASHRAE Standard 90-75 and alternate fenestration designs. Although the computerized thermal analysis and the daylight analysis had to be done separately, actual weather data and corresponding daylight readings for Ann Arbor, Michigan are used for both. Results show a potential energy savings when daylighting is carefully integrated into the building's envelope design, especially for southern exposures, but such savings will be realized only if applied with the other energy variables in mind.

20551. Batts, M. E.; Changery, M. J. **Wind speed averaging-time relationship: Experimental data,** *Proc. ASCE Annu. Fall Conv., Hollywood, FL, Oct. 27-31, 1980,* 10 pages (American Society of Civil Engineers, New York, NY, Oct. 1980).

Key words: climatology; statistical analysis; wind (meteorology).

In the United States, the most common maximum windspeed measurements, for use in engineering calculations, are in units of fastest miles. Other measurements consist of averaged windspeed over longer intervals.

Due to the way current code procedures to determine dynamic wind loads involve mean wind speeds, some conversion relation is necessary in order to compare these velocities.

This paper deals with the problems associated with experimentally measuring the parameters of a conversion relation between windspeeds averaged over various time intervals.

20605. Hunt, C. M.; Treado, S. J. **Air exchange measurements in a high-rise office building,** (Proc. ASHRAE/DOE/ORNL Conf. on Thermal Performance of Exterior Envelope of Buildings, Orlando, FL, Dec. 3-5, 1979), *ASHRAE SP* **28,** pp. 160-177 (American Society of Heating, Refrigeration and Air-Conditioning Engineers, New York, NY, 1981).

Key words: building air exchange; commercial building ventilation; energy consumption by buildings; office building ventilation; ventilation analysis; weather and building air exchange.

Air exchange rates were measured in the tower of an 11-story office building using SF_6 as a tracer gas. Fall and winter air exchange rates, I (hr^{-1}), measured with make-up and main exhaust pathways blocked, could be represented as a function of wind spread, W (mi/hr), by the equation $I = 1.08 + 0.036W - 0.0005W^2$, $\sigma = 0.15$.

Wind direction and temperature difference (stack effect) exerted little effect on air exchange rate. In this building, toilet exhausts and other weather-independent mechanisms were more important than natural infiltration in producing air exchange. Inside-outside pressure difference measurements were monitored as a function of temperature and wind speed. Also, a preliminary analysis of predicted air infiltration by the Shaw-Tamura model was undertaken. The results of this preliminary analysis were consistent with the observations that the stack effect was unimportant and that natural infiltration contributed only part of the total air exchange. However, the plot of calculated infiltration rate as a function of wind speed, using the Shaw-Tamura model, had a different form than the plot of measured data.

20648. Fanney, A. H.; Thomas, W. C. **Simulation of thermal performance of solar collector arrays,** *Trans. ASME* **103,** 258-267 (Aug. 1981).

Key words: collector; indoor; outdoor; parallel; series; simulation; solar; testing.

An experimental method is described for simulating the useful energy supplied by collector arrays during tests of solar water heating systems. The method uses an electric heat source to simulate the absorbed solar energy in series with nonirradiated collectors to simulate the concurrent heat losses. This configuration maintains the collector-loop flow characteristics which are important for system tests.

Expressions are developed for programming the heat source for collector arrays connected in parallel and series combinations with the heat source located either upstream or downstream from the nonirradiated array. Thermal modelling of representative arrays is used to investigate the consequences of using linearized collector efficiency curves to program the heat source and of using nonirradiated collectors to simulate heat losses. The absence of absorbed solar radiation in collector covers indoors is shown to partially cancel the effects of generally higher windspeeds and increased longwave radiation from the outdoor environment.

The results of experiments to verify the performance of a nonirradiated array with a downstream electric heat source are presented. Day-long tests of a domestic solar hot water system with irradiated collectors were repeated using a nonirradiated array with a downstream heat source. The useful energy supplied in the two cases agreed to within 3.5 percent. The measured differences were consistent with the results of the analytical investigation. In representative situations, the use of nonirradiated collectors in series with an electric heat source may give up to 10 percent higher useful energy output as compared to an irradiated array. However, differences can be reduced by closely matching indoor and outdoor environmental conditions and by locating the heat source downstream from the nonirradiated collector array.

20690. Parken, W. H.; Kelly, G. E. **Estimating residential seasonal cooling requirements,** (Proc. ASHRAE 1981 Semi-Annu. Meet., Chicago, IL, Jan. 25-29, 1981), *ASHRAE Trans.* **87,** Pt. 1, 473-490 (1981).

Key words: airconditioning cooling load; cooling load; residential cooling; seasonal cooling; temperature bin.

A method is presented (referred to as the modified building load and temperature bin method, MBLTBM) for calculating residential building cooling loads and seasonal cooling requirements for various geographical regions. The method incorporates the effects of solar radiation, internal heat gains, outdoor temperature, infiltration, and thermal response on the cooling load for different periods of the day.

The MBLTBM can be used with improved precision over existing "simple" calculation procedures without the use of large, sophisticated and time consuming computer programs. The increased precision in determining seasonal cooling requirements can result in improved estimates of the cost of operating airconditioning equipment.

The method requires little additional data to what are presently required for calculating design cooling requirements. For the region of interest, temperature bin data (the number of hours during the cooling season the temperature, in 5°F (2.8°C) increments, occurs), the summer daily average temperature, and the average daily extreme temperatures are required and readily obtainable. Also needed for the calculation procedure are the solar heat gain factors for windows and incident solar radiation on vertical and horizontal opaque surfaces.

The modified building load and temperature bin method was compared to the more comprehensive method obtained by the hour-by-hour cooling loads as determined by the BLAST computer program, and by results obtained by hand calculation presently in common use. The comparisons were made for a variety of residential structures, localities and orientations.

20705. Waksman, D. **Solar collector certification activities and experiences,** *Proc. Commercial Photovoltaics Measurements Workshop, Vail, CO, July 27-29, 1981,* pp. 279-289 (Available from the National Technical Information Service, Springfield, VA, Nov. 1981).

Key words: certification; experiences; issues and concerns; laboratory accreditation; solar collector; standards.

This paper is intended to provide organizations which may be involved in the development of certification programs for photovoltaic (PV) solar modules with the benefit of the experience gained to date in the development of certification programs for solar collectors. The various public and private sector certification activities that have been undertaken for solar collectors along with issues and concerns that have arisen from their use are presented.

20735. Siu, M. C. I.; Bulik, C. **National Bureau of Standards line-heat-source guarded-hot-plate apparatus,** *Rev. Sci. Inst.* **52,** No. 11, 1709-1716 (Nov. 1981).

Key words: edge heat loss; effective thermal conductivity; gap-temperature unbalance; guarded-hot-plate; heat source distribution; insulation; thermal conductivity.

A description is given of a line-heat-source guarded-hot-plate apparatus for determining the effective thermal conductivity of insulation materials from 250 K to 400 K. Measurements made on fibrous glass boards are in good agreement with results obtained from the guarded-hot-plate apparatus in operation at the National Bureau of Standards for over 40 years.

20752. Clark, R. E. **Weatherization retrofitting and occupant comfort,** (Proc. Nat. Conf. Optimal Weatherization, Washington, DC, Dec. 8-10, 1980), Paper in *Optimal Weatherization,* pp. 60-67 (Information Dynamics, Inc., 111 Claybrook Dr., Silver Spring, MD 20902, 1981).

Key words: comfort; Community Services Administration Optimal Weatherization Demonstration; energy savings; field study; thermal comfort; weatherization retrofitting.

This report discusses preliminary findings of a field study of occupant comfort impressions in weatherized houses. The research was carried out as a part of the Community Services Administration National Optimal Weatherization Demonstration. Data were obtained from 145 households in nine of the Demonstration site cities by means of questionnaire-guided interviews. Approximately 25 percent of the surveyed households lived in control houses that were not weatherized. The data covered: 1) thermostat setting practices; 2) comparative amounts of clothing worn; 3) direct report of comparative comfort; 4) comfort ratings (on a five-point scale) and temperature ratings (on the ASHRAE seven-point scale). Twenty percent of the respondents were not sure about their recollections of comfort impressions. Preliminary analysis of the remaining 109 cases (again, 25 percent control houses) gave encouraging indications that occupants of houses that get retrofitted with weatherization measures are likely to notice improvement in wintertime comfort. Further, almost one-half of the households in weatherized houses having thermostats reported less propensity to turn up thermostats during

unusually cold weather after their houses were weatherized than before, a change that should result in additional energy savings beyond those directly attributable to the weatherization retrofitting.

20754. Kusuda, T.; Bean, J. W. **Comparison of calculated hourly cooling load and indoor temperature with measured data for a high mass building tested in an environmental chamber,** (Proc. ASHRAE Semi. Ann. Meet., Chicago, IL, Jan. 1981), *ASHRAE Trans.* **87,** Pt. 1, 1232-1242 (1981).

Key words: desert climate; energy calculation; environmental chamber; heating/cooling load; nighttime cooling.

A one-room high mass test building designed for a hot and dry desert climate was tested in the NBS environmental chamber under simulated diurnal cycles representing typical summer sol-air temperature profiles. The measured nighttime cooling requirement as well as the daytime temperature drifts were compared against the calculated values obtained from the detailed hourly simulation computer program. The purpose of the tests was to prove the effectiveness of nighttime cooling when the cooling efficiency is high, and subsequent use of the stored coolness in the structure to eliminate daytime mechanical cooling when the cooling efficiency is low. Although the NBSLD calculated daytime temperature-rise profiles are very close to what was measured, the calculated cooling load profile differed from the measured data. The differences are, however, attributable to the large amount of latent cooling load resulting from the release of moisture from the structural concrete.

20755. Kusuda, T.; Pierce, E. T.; Bean, J. W. **Comparison of calculated hourly cooling load and attic temperature with measured data for a Houston test house,** (Proc. ASHRAE Semi Ann. Meet., Chicago, IL, Jan. 1981), *ASHRAE Trans.* **87,** Pt. 1, 1185-1199 (1981).

Key words: attic temperature; BLAST; computer simulation; DoE-2; heating/cooling load calculation; indoor temperature; NBSLD.

During the summer and autumn of 1977, NBS conducted attic ventilation experiments in three test houses in Houston, Texas. Hourly cooling loads were measured, together with indoor/outdoor climatic data, to allow precise comparison between the computer-simulated values with those measured values. In this paper, measured hourly cooling loads as well as attic temperature of one of the test houses were compared with those determined by the detailed heat balance simulation calculation used in NBSLD, the National Bureau of Standards heating/cooling load determination program. Measured cooling loads for a steady three-day period were also compared with those determined by two other public domain energy simulation programs, DoE-2 and BLAST-2.

20756. Kusuda, T.; Sud, I.; Alereza, T. **Comparison of DOE-2-generated residential design energy budgets with those calculated by the degree-day and bin methods,** (Proc. ASHRAE Semi Ann. Meet., Chicago, IL, Jan. 1981), *ASHRAE Trans.* **87,** Pt. 1, 491-506 (1981).

Key words: bin method; building energy performance standards (BEPS); degree-day; DOE-2.

Residential design energy budgets for the buildings energy performance standards were generated by the use of the DOE-2 computer program for four different types of structures in 10 different localities throughout the U.S. The DOE-2 calculations for these conditions were repeated by simplified procedures using the degree-day and bin methods. By modifying the basis for the degree-day data from 65°F to building specific value, remarkably close agreements were obtained between the DOE-2 and the degree-day results. Also, good agreements were obtained between the DOE-2 results and the ASHRAE TC4.7 method.

20758. Kusuda, T. **Standards criteria for HVAC systems and equipment performance simulation procedures,** *ASHRAE J.* **23,** 25-28 (Oct. 1981).

Key words: Building Energy Performance Standards (BEPS); energy calculations; HVAC systems and equipment; validation.

Systems simulations have been considered an essential part of the building energy calculations used for regulations such as the Building Energy Performance Standards. Regardless of whether or not the BEPS survive political changes with the current administration, these are still critical ingredients for HVAC equipment analysis and accurate energy calculations.

20759. Mehta, K. C.; Minor, J. E.; Marshall, R. D.; Reinhold, T. A. **Wind speed-damage correlation in Hurricane Frederic,** *Proc. ASCE Convention and Exposition, St. Louis, MO, Oct. 26-30, 1981,* 14 pages (American Society of Civil Engineers, New York, NY 10017, Nov. 1981).

Key words: building performance; hurricane winds; structural damage; structures; wind; wind speed.

Damage to buildings and other structures caused by Hurricane Frederic's winds is reviewed and classified by level of engineering design and by range of maximum wind speed. Observations concerning the performance of buildings and structures are grouped according to whether the buildings and structures are fully engineered, pre-engineered, marginally engineered, or non-engineered. A major emphasis is placed on estimating wind speeds, at sites of damage observations, from anemometer data. Wind speed data is converted to equivalent maximum fastest-mile wind speeds at elevations of 10 meters over open terrain. Performance observations are further correlated with fastest-mile wind speed ranges of 70–85 mph, 85–100 mph, and 100–110 mph. These observations indicate that significant damage did not occur until wind speeds reached or exceeded design values.

20764. Simiu, E.; Shaver, J. R.; Filliben, J. J. **Extreme wind speeds and structural failure risks,** (Proc. Conf. Climate and Risk, Arlington, VA, May 27-29, 1980), Paper *MTR-80W322-01 in Climate and Risk,* L. S. Pocinki and R. S. Greeley, eds., **1,** 2-86—2-100 (The MITRE Corporation, McLean, VA 22102, Nov. 1980).

Key words: building (codes); climatology; hurricanes; reliability; risk; structural engineering.

A first objective of the paper is to describe recent NBS research results in the field of extreme wind climatology. These results include the finding that at most locations in the U.S. extreme wind speeds are described by probabilistic models with considerably shorter tails than the Extreme Value Type I distribution. Estimates of hurricane wind speeds along the Gulf and East coasts are presented, based on Monte Carlo simulation techniques used in conjunction with statistical data on the climatological characteristics of hurricanes. Also presented in the paper are estimates of member reliabilities that take into account the various uncertainties concerning the behavior of the member during its anticipated life. The dependence of such estimates upon the assumed probability distribution of the extreme wind speeds is discussed, and it is shown that current reliability estimates based on an Extreme Value Type I model of the extreme wind speeds appear to be unduly pessimistic.

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earthquake; seismic risk; standards, building; building codes; building regulatory system; buildings; building standards; codes, building; *20386.*

earthquake; seismic risk maps; standards; structural engineering; buildings; buildings (codes); buildings (design); *NBSIR 80-2111-1.*

earthquake loads; hail loads; snow loads; solar collectors; structural engineering; wind loads; *NBSIR 81-2199.*

earthquake-resistant design; seismic design; systems analysis; building; building codes; building standards; *20435.*

earthquakes; engineering; Federal government; seismic safety; standards; structural engineering; building; building design; *NBSIR 81-2195.*

earthquakes; engineering; foundations; professional practice; provisions; soil structure interaction; standards; buildings; design; *NBSIR 80-2111-3.*

earthquakes; engineering; masonry; standards; structural engineering; building; building codes; building design; *NBSIR 80-2111-5.*

earthquakes; engineering; reinforced concrete; standards; structural engineering; building; building codes; building design; *NBSIR 80-2111-4.*

earthquakes; engineering; standards; steel; structural engineering; building; building codes; building design; *NBSIR 80-2111-6.*

earthquakes; engineering; standards; structural engineering; building; building codes; building design; *NBSIR 80-2111-11.*

earthquakes; engineering; standards; structural engineering; wood; building; building codes; building design; *NBSIR 80-2111-7.*

earth temperature; heat transfer; pipes; thermal insulation; thermal properties; underground systems; computer program; *NBSIR 81-2378.*

economic analysis; economic decision framework; energy conservation; marginal price; net present value; residential water conservation; wastewater treatment; water rate schedules; water-saving devices; benefits; cost-effective; costs; *NBSIR 81-2304.*

economic analysis; energy analysis; energy conservation; Federal programs; government buildings; hospitals; rate of return; schools; technical assistance; certification; Class A energy audit; *SP608*; 1981 May. 133-138.

economic analysis; energy conservation; insulation; labor cost; low-income housing; materials cost; statistics; unit costs; weatherization; building economics; data analysis; data collection; *20499.*

economic analysis; energy conservation; investment analysis; life-cycle cost; recommended practice; savings-to-investment ratio; benefit-cost analysis; building economics; cost effective; *NBSIR 81-2397.*

economic decision framework; energy conservation; marginal price; net present value; residential water conservation; wastewater treatment; water rate schedules; water-saving devices; benefits; cost-effective; costs; economic analysis; *NBSIR 81-2304.*

economic evaluations; energy conservation; Federal energy management program; life-cycle costing; public buildings; renewable energy; solar energy; solar photovoltaic; cost effectiveness; *H135.*

economic impact; economics; energy; model code; noise control; acoustical design; acoustics; architectural design; building codes; building economics; construction costs; cost minimization; *NBSIR 81-2366.*

economic optimization; life-cycle costing; solar economics; solar energy; *NBSIR 81-2342.*

economics; energy; model code; noise control; acoustical design; acoustics; architectural design; building codes; building economics; construction costs; cost minimization; economic impact; *NBSIR 81-2366.*

economics; energy conservation codes; fire safety codes; regulation; benefit-cost analysis; building economics; building regulation; codes; construction regulation; *NBSIR 81-2223.*

economics; Federal buildings; life-cycle costs; solar energy; *20151.*

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heat source distribution; insulation; thermal conductivity; edge heat loss; effective thermal conductivity; gap-temperature unbalance; guarded-hot-plate; *20735.*

heat transfer; hot water; measurement; solar; testing; energy; *20103.*

heat transfer; pebble-bed storage; solar collector; system efficiency; thermal performance; air leakage; *NBS-GCR-81-302.*

heat transfer; pipes; thermal insulation; thermal properties; underground systems; computer program; earth temperature; *NBSIR 81-2378.*

heat transfer; radiosity shape factors; building heating/cooling loads; heat balance for a single room; *NBSIR 81-2321.*

heat transfer fluid; solar collector; thermal performance; efficiency; flow rate; *NBS-GCR-80-254.*

high voltage; human response to noise; noise pollution; psychoacoustics; transmission line audible noise; corona noise; electric energy transmission; *20029.*

high voltage transmission lines; human response to noise; listening room; corona noise; environmental noise; *20030.*

high-voltage transmission lines; human response to noise; modification of noise spectra; aversiveness measures; corona noise; environmental noise impact; *20361.*

historic; passive solar; retrofit; solar greenhouse; Trombe wall; *20440.*

historic preservation and energy conservation; load calculation; masonry thermal mass; system simulation; building energy analysis; energy conservation for nonresidential buildings; *NBSIR 81-2317.*

history; horizontal; length; partially-filled; pipe; slope; stream-depth; unsteady; volume; water; diameter; drain; flow; *NBSIR 81-2249.*

horizontal; length; partially-filled; pipe; slope; stream-depth; unsteady; volume; water; diameter; drain; flow; history; *NBSIR 81-2249.*

horizontal; measurements; partially-filled; pipe flow; solid; unsteady; velocity; water; depth-time history; *20147.*

hospitals; rate of return; schools; technical assistance; certification; Class A energy audit; economic analysis; energy analysis; energy conservation; Federal programs; government buildings; *SP608*; 1981 May. 133-138.

hot water; measurement; solar; testing; energy; heat transfer; *20103.*

household behavior patterns; housing characteristics (physical); housing security; public housing security; security hardware; victimization survey; burglary; crime in public housing; *NBS-GCR-80-291.*

housing; interiors; lifestyle; research; site planning; sociology; standards; children; design; environmental psychology; families; *NBS-GCR-81-320.*

housing; Operation Breakthrough; post-occupancy housing evaluation; Project Feedback; questionnaires; research methods; survey research; user needs; dwelling units (residential); *NBSIR 81-2258.*

housing; productivity; regulation; renovation; building codes; building economics; construction; cost; economics; *NBSIR 80-2150.*

housing characteristics (physical); housing security; public housing security; security hardware; victimization survey; burglary; crime in public housing; household behavior patterns; *NBS-GCR-80-291.*

housing codes; maintenance; model codes; occupancy; performance levels; regulation; standards; building rehabilitation; codes; comparative analysis; existing buildings; *NBSIR 80-2081.*

housing construction; mine subsidence; mining; settlement; structural design; structural engineering; design criteria; foundation design; geotechnical engineering; *NBSIR 81-2215.*

housing research; housing standards; performance requirements; standards development; building energy use; building service systems; energy budgets; *NBS-GCR-80-280.*

housing security; public housing security; security hardware; victimization survey; burglary; crime in public housing; household behavior patterns; housing characteristics (physical); *NBS-GCR-80-291.*

housing standards; performance requirements; standards development; building energy use; building service systems; energy budgets; housing research; *NBS-GCR-80-280.*

HUD initiative; performance standards; solar collectors; solar water heaters; storage tanks; thermal performance; f-chart; *20121.*

human response to noise; listening room; corona noise; environmental noise; high voltage transmission lines; *20030.*

human response to noise; modification of noise spectra; aversiveness measures; corona noise; environmental noise impact; high-voltage transmission lines; *20361.*

human response to noise; noise pollution; psychoacoustics; transmission line audible noise; corona noise; electric energy transmission; high voltage; *20029.*

humidity, thermal insulation and corrosion of electrical wiring; shock hazards; urea-formaldehyde thermal insulation; cellulose thermal insulation; corrosion of electrical outlet boxes and devices; electrical devices; *NBSIR 81-2220.*

hurricane forces; mobile home; soil anchors; standards; tiedown; wind forces; buoyancy forces; flood forces; foundations; *BSS132.*

hurricanes; micrometeorology; structures; tornadoes; wind engineering; wind profiles; atmospheric turbulence; buildings; design (structural); extreme winds; *20525.*

hurricanes; reliability; risk; structural engineering; building (codes); climatology; *20764.*

hurricane winds; structural damage; structures; wind; wind speed; building performance; *20759.*

HVAC; masonry; plumbing; solar; steel; structural systems; test methods; wood; building rehabilitation; concrete; electrical; evaluation; *NBSIR 81-2289.*

HVAC; masonry; plumbing; steel; structural systems; test methods; wood; building rehabilitation; concrete; electrical; evaluation; *NBSIR 80-2171.*

HVAC calculations; insulation; life-cycle cost analysis; masonry; mass; building design; building economics; energy conservation; exterior wall; *BSS134.*

HVAC controls; reliability study; building energy conservation systems; EMCS; energy management; energy monitoring and control systems; *NBSIR 81-2346.*

HVAC systems; innovation; mathematical model; optimization; cost savings; energy conservation; *SP608*; 1981 May. 21-35.

HVAC systems; performance standards; solar collector; solar energy; space heating and cooling; thermal storage; ASHRAE 90-75; class K code; computer modeling; electrical design; energy audit; energy conservation; *SP608.*

HVAC systems and equipment; validation; Building Energy Performance Standards (BEPS); energy calculations; *20758.*

hybrid solar energy system; inverted cave; low grade geothermal; radiant floor heating; space heating and cooling; thermal mass; walls; water source heat pump; buildings; construction; energy conservation; ground coupled; *SP608*; 1981 May. 69-81.

hydration; initial set; laboratory testing; maturity; mortar; regression analysis; strength prediction; temperature effects; compressive strength; concrete; curing temperature; early age; final set; *NBSIR 81-2244.*

hydraulic jump; partially filled pipe flow; building drainage; gradually varied flow; *NBSIR 81-2367.*

hydronic heating; pulse combustion; boilers; central heating; condensing boilers; efficiency, part load; fossil-fuel heating systems; gas-fired boilers; *NBSIR 80-2094.*

I

Illinois; maintenance; public buildings; state government; cost; construction; energy audit; energy conservation; *SP608*; 1981 May. 123-132.

illuminance; illumination; irradiance; solar radiation; daylighting; *TN1148.*

illumination; irradiance; solar radiation; daylighting; illuminance; *TN1148.*

illumination; lighting; lighting levels; superthreshold visibility; vision; conspicuity; contrast; *NBSIR 81-2231.*

illumination; lighting control; solar heat gain; window management; daylight; energy conservation; fenestration design; *NBSIR 80-2147.*

impact noise; noise control; noise isolation; noise rating; acoustics; building acoustics; *NBS-GCR-80-249.*

indoor; outdoor; parallel; series; simulation; solar; testing; collector; *20648.*

indoor temperature; NBSLD; attic temperature; BLAST; computer simulation; DoE-2; heating/cooling load calculation; *20755.*

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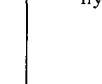

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APPENDICES

APPENDIX A. DEPOSITORY LIBRARIES IN THE UNITED STATES

ALABAMA

Alexander City: Alexander City State Junior College, Thomas D. Russell Library (1967).
Auburn: Auburn University, Ralph Brown Draughon Library (1907).
Birmingham:
- Birmingham Public Library (1895).
- Birmingham Southern College Library (1932).
- Jefferson State Junior College, James B. Allen Library (1970).
- Samford University Library (1884).

Enterprise: Enterprise State Junior College, Learning Resources Center (1967).
Florence: University of North Alabama, Collier Library (1932).
Gadsden: Gadsden Public Library (1963).
Huntsville: University of Alabama in Huntsville Library (1964).
Jacksonville: Jacksonville State University Library (1929).
Mobile:
- Mobile Public Library (1963).
- Spring Hill College, Thomas Byrne Memorial Library (1937).
- University of South Alabama Library (1968).

Montgomery:
- Alabama State Department of Archives and History Library (1884).
- Alabama Supreme Court and State Law Library (1884).
- Auburn University at Montgomery Library (1971)-REGIONAL.

Maxwell A.F. Base: Air University Library (1963).
Normal: Alabama Agricultural and Mechanical College, J. F. Drake Memorial Library (1963).
Troy: Troy State University, Lurleen B. Wallace Educational Resources Center (1963).
Tuskegee Institute: Tuskegee Institute, Hollis Burke Frissell Library (1907).
University:
- University of Alabama Library (1860)-REGIONAL.
- University of Alabama, School of Law Library (1967).

ALASKA

Anchorage:
- Anchorage Municipal Libraries, Z. J. Loussac Public Library (1978).
- Supreme Court of Alaska Library (1973).
- University of Alaska at Anchorage Library (1961).

Fairbanks: University of Alaska, Elmer E. Rasmuson Library (1922).
Juneau: Alaska State Library (1900).
Ketchikan: Ketchikan Community College Library (1970).

ARIZONA

Coolidge: Central Arizona College, Instructional Materials Center (1973).
Flagstaff: Northern Arizona University Library (1937).
Phoenix:
- Department of Library, Archives, and Public Records (unknown)-REGIONAL.
- Grand Canyon College, Fleming Library (1978).
- Phoenix Public Library (1917).

Prescott: Yavapai College Library (1976).
Tempe:
- Arizona State University, College of Law Library (1977).
- Arizona State University Library (1944).

Thatcher: Eastern Arizona College Library (1963).
Tucson:
- Tucson Public Library (1970).
- University of Arizona Library (1907)-REGIONAL.

Yuma: Yuma City-County Library (1963).

ARKANSAS

Arkadelphia: Ouachita Baptist University, Riley Library (1963).
Batesville: Arkansas College, Mabee Learning Resources Center (1963).
Clarksville: College of the Ozarks, Dobson Memorial Library (1925).
Conway: Hendrix College, Olin C. Bailey Library (1903).
Fayetteville:
- University of Arkansas Library (1907).
- University of Arkansas, School of Law Library (1978).

Little Rock:
- Arkansas Library Commission (1978).
- Arkansas Supreme Court Library (1962).
- Little Rock Public Library (1953).
- University of Arkansas at Little Rock Library (1973).

Magnolia: Southern Arkansas University, Magale Library (1956).
Monticello: University of Arkansas at Monticello Library (1956).
Pine Bluff: University of Arkansas at Pine Bluff, Watson Memorial Library (1976).
Russellville: Arkansas Tech University, Tomlinson Library (1925).
Searcy: Harding College, Beaumont Memorial Library (1963).
State University: Arkansas State University, Dean B. Ellis Library (1913).
Walnut Ridge: Southern Baptist College, Felix Goodson Library (1967).

CALIFORNIA

Anaheim: Anaheim Public Library (1963).
Arcadia: Arcadia Public Library (1975).
Arcata: Humboldt State College Library (1963).
Bakersfield:
- California State College at Bakersfield Library (1974).
- Kern County Library (1943).

Berkeley:
- University of California, Earl Warren Legal Center, Law Library (1963).
- University of California, General Library (1907).

Carson:
- California State University, Dominguez Hill Education Resources Center (1973).
- Carson Regional Library (1973).

Chico: California State University at Chico Library (1962).
Claremont: Claremont Colleges' Libraries, Honnold Library (1913).
Coalinga: West Hills Community College Library (1978).
Compton: Compton Library (1972).
Culver City: Culver City Library (1966).

Davis:
University of California at Davis Library (1953).
University of California at Davis, School of Law Library (1972).
Downey: Downey City Library (1963).
Fresno:
California State University at Fresno Library (1962).
Fresno County Free Library (1920).
Fullerton: California State University at Fullerton Library (1963).
Garden Grove: Garden Grove Regional Library (1963).
Gardena: Gardena Public Library (1966).
Hayward: California State University at Hayward Library (1963).
Huntington Park: Huntington Park Library, San Antonio Region (1970).
Inglewood: Inglewood Public Library (1963).
Irvine: University of California at Irvine, General Library (1963).
La Jolla: University of California, San Diego, University Library (1963).
Lakewood: Angelo Iacoboni Public Library (1970).
Lancaster: Lancaster Regional Library (1967).
La Verne: University of La Verne, School of Law Library (1979).
Long Beach:
California State University at Long Beach Library (1962).
Long Beach Public Library (1933).
Los Angeles:
California State University at Los Angeles, John F. Kennedy Memorial Library (1956).
Los Angeles County Law Library (1963).
Los Angeles Public Library (1891).
Loyola University of Los Angeles Library (1933).
Loyola University, School of Law Library (1979).
Occidental College Library (1941).
Pepperdine University Library (1963).
Southwestern University, School of Law Library (1975).
University of California at Los Angeles Library (1932).
University of California at Los Angeles, Law Library (1958).
University of Southern California Library (1933).
University of Southern California, Law Center Library (1978).
Whittier College, School of Law Library (1978).
Menlo Park: Department of the Interior, Geological Survey Library (1962).
Montebello: Montebello Library (1966).
Monterey: U.S. Naval Postgraduate School, Dudley Knox Library (1963).
Monterey Park: Bruggemeyer Memorial Library (1964).
Northridge: California State University at Northridge Library (1958).
Norwalk: Norwalk Public Library (1973).
Oakland:
Mills College Library (1966).
Oakland Public Library (1923).
Ontario: Ontario City Library (1974).
Pasadena:
California Institute of Technology, Millikan Memorial Library (1933).
Pasadena Public Library (1963).
Pleasant Hill: Contra Costa County Library (1964).
Redding: Shasta County Library (1956).
Redlands: University of Redlands, Armacost Library (1933).
Redwood City: Redwood City Public Library (1966).
Reseda: West Valley Regional Branch Library (1966).
Richmond: Richmond Public Library (1943).
Riverside:
Riverside Public Library (1947).
University of California at Riverside Library (1963).
Sacramento:
California State Library (1895)-REGIONAL.
California State University at Sacramento Library (1963).
Sacramento County Law Library (1963).
Sacramento Public Library (1880).
University of the Pacific, McGeorge School of Law Library (1978).
San Bernardino: San Bernardino County Free Library (1964).
San Diego:
San Diego County Law Library (1973).
San Diego County Library (1966).
San Diego Public Library (1895).
San Diego State University, Malcoln A. Love Library (1962).
University of San Diego, School of Law Library (1967).
San Francisco:
Golden Gate University, School of Law Library (1979).
Hastings College of Law Library (1972).
Mechanics' Institute Library (1889).
San Francisco Public Library (1889).
San Francisco State College, Paul Leonard Library (1955).
Supreme Court of California Library (1979).
U.S. Court of Appeals, Ninth Circuit Library (1971).
University of San Francisco, Richard A. Gleeson Library (1963).
San Jose: San Jose State University Library (1962).
San Leandro: San Leandro Community Library Center (1961).
San Luis Obispo: California State Polytechnic University Library (1969).
San Rafael: Marin County Free Library (1975).
Santa Ana:
Orange County Law Library (1975).
Santa Ana Public Library (1959).
Santa Barbara: University of California at Santa Barbara Library (1960).
Santa Clara: University of Santa Clara, Orradre Library (1963).
Santa Cruz: University of California at Santa Cruz Library (1963).
Santa Rosa: Santa Rosa-Sonoma County Public Library (1896).
Stanford:
Stanford University Libraries (1895).
Stanford University, Robert Crown Law Library (1978).
Stockton: Public Library of Stockton and San Joaquin County (1884).
Thousand Oaks: California Lutheran College Library (1964).
Torrance: Torrance Civic Center Library (1969).
Turlock: California State University at Stanislaus Library (1964).
Valencia: Valencia Regional Library (1972).
Ventura: Ventura County Library Services Agency (1975).
Visalia: Tulare County Free Library (1967).
Walnut: Mount San Antonio College Library (1966).
West Covina: West Covina Library (1966).
Whittier: Whittier College, Wardman Library (1963).

CANAL ZONE

Balboa Heights: Canal Zone Library-Museum (1963).

COLORADO

Alamosa: Adams State College, Learning Resources Center (1963).
Boulder: University of Colorado Libraries (1879)-REGIONAL.
Colorado Springs:
Colorado College, Tutt Library (1880).
University of Colorado, Colorado Springs Library (1974).
Denver:
Auraria Libraries (1978).
Colorado State Library (unknown).
Colorado Supreme Court Library (1978).
Denver Public Library (1884)-REGIONAL.

Department of the Interior, Bureau of Reclamation Library (1962).
Regis College, Dayton Memorial Library (1915).
University of Denver, Penrose Library (1909).
University of Denver, School of Law Library (1978).
U.S. Court of Appeals, Tenth Circuit Library (1973).
Fort Collins: Colorado State University Libraries (1907).
Golden: Colorado School of Mines, Arthur Lakes Library (1939).
Grand Junction: Mesa County Public Library (1975).
Greeley: University of Northern Colorado Library (1966).
Gunnison: Western State College, Leslie J. Savage Library (1932).
La Junta: Otero Junior College, Wheeler Library (1963).
Lakewood: Jefferson County Public Library, Lakewood Regional Library (1968).
Pueblo:
Pueblo Regional Library (1893).
University of Southern Colorado Library (1965).
U.S. Air Force Academy: Academy Library (1956).

CONNECTICUT

Bridgeport: Bridgeport Public Library (1884).
Danbury: Western Connecticut State College, Ruth A. Haas Library (1967).
Danielson: Quinebaug Valley Community College (1975).
Enfield: Enfield Public Library (1967).
Hartford:
Connecticut State Library (unknown)–REGIONAL.
Hartford Public Library (1945).
Trinity College Library (1895).
Middletown: Wesleyan University, Olin Library (1906).
Mystic: Marine Historical Association, Inc., G. W. Blunt White Library (1964).
New Britain: Central Connecticut State College, Elihu Burritt Library (1973).
New Haven:
Southern Connecticut State College, Hilton C. Buley Library (1968).
Yale University Library (1859).
New London:
Connecticut College Library (1926).
U.S. Coast Guard Academy Library (1939).
Stamford: The Ferguson Library (1973).
Storrs: University of Connecticut Library (1907).
Waterbury:
Post College, Traurig Library (1977).
Silas Bronson Public Library (1869).
West Hartford: University of Connecticut, School of Law Library (1978).
West Haven: University of New Haven Library (1971).

DELAWARE

Dover:
Delaware State College, William C. Jason Library (1962).
Department of Community Affairs and Economic Development, Division of Libraries (1972).
State Law Library in Kent County (unknown).
Georgetown:
Delaware Technical and Community College Library (1968).
Sussex County Law Library (1976).
Newark: University of Delaware, Morris Library (1907).
Wilmington:
Delaware Law School Library (1976).
New Castle County Law Library (1974).
Wilmington Institute and New Castle County Library (1861).

DISTRICT OF COLUMBIA

Washington:
Administrative Conference of the United States Library (1977).
Advisory Commission on Intergovernmental Relations Library (1972).
Catholic University of America, Columbus School of Law, Robert J. White Law Library (1979).
Civil Aeronautics Board Library (1974).
Department of the Army Library (1969).
Department of Commerce Library (1955).
Department of Energy Library (1963).
Department of Health, Education, and Welfare Library (1954).
Department of Housing and Urban Development Library (1969).
Department of the Interior Library (1895).
Department of Justice Main Library (1895).
Department of Labor Library (1976).
Department of the Navy Library (1895).
Department of the Navy, Office of the Judge Advocate General Library (1963).
Department of State Library (1895).
Department of State Law Library (1966).
Department of Transportation, National Highway Traffic Safety Administration Library (1968).
Department of the Treasury Library (1895).
District of Columbia Public Library (1943).
Executive Office of the President, Office of Management and Budget Library (1965).
Federal Deposit Insurance Corporation Library (1972).
Federal Election Commission Library (1975).
Federal Reserve System, Board of Governors Research Library (1978).
Federal Reserve System Law Library (1976).
General Accounting Office Library (1974).
General Services Administration Library (1975).
Georgetown University Library (1969).
Georgetown University Law Center, Fred O. Dennis Law Library (1978).
George Washington University, National Law Center (1978).
Library of Congress, Congressional Research Service (1978).
Library of Congress, Exchange and Gift Division (1977).
Merit Systems Protection Board Library (1979).
National Defense University Library (1895).
University of the District of Columbia, Mount Vernon Campus Library and Media Center (1970).
U.S. Court of Appeals, Judges' Library (1975).
U.S. Office of Personnel Management Library (1963).
U.S. Postal Service Library (1895).
U.S. Supreme Court Library (1978).
Veterans' Administration, Central Office Library (1967).

FLORIDA

Boca Raton: Florida Atlantic University Library (1963).
Clearwater: Clearwater Public Library (1972).
Coral Gables: University of Miami Library (1939).
Crestview: Robert F. L. Sikes Public Library (1978).
Daytona Beach: Volusia County Public Libraries (1963).
De Land: Stetson University, duPont-Ball Library (1887).
Fort Lauderdale:
Broward County Library System (1967).
Nova University Law Library (1967).
Fort Pierce: Indian River Community College Library (1975).
Gainesville:
University of Florida, Holland Law Center, School of Law Library (1978).
University of Florida Libraries (1907)–REGIONAL.

Jacksonville:
- Haydon Burnes Library (1914).
- Jacksonville University, Swisher Library (1962).
- University of North Florida Library (1972).

Lakeland: Lakeland Public Library (1928).
Leesburg: Lake-Sumter Community College Library (1963).
Melbourne: Florida Institute of Technology Library (1963).
Miami:
- Florida International University Library (1970).
- Miami Public Library (1952).

North Miami: Florida International University, North Miami Campus Library (1977).
Opa Locka: Biscayne College Library (1966).
Orlando: Florida Technological University Library (1966).
Palatka: St. Johns River Junior College Library (1963).
Pensacola: University of West Florida, John C. Pace Library (1966).
Punta Gorda: Charlotte County Library System (1973).
St. Petersburg:
- St. Petersburg Public Library (1965).
- Stetson University, College of Law Library (1975).

Sarasota: Selby Public Library (1970).
Tallahassee:
- Florida Agricultural and Mechanical University, Coleman Memorial Library (1936).
- Florida State University, College of Law Library (1978).
- Florida State University, Robert M. Stozier Library (1941). (1941).
- Florida Supreme Court Library (1974).
- State Library of Florida (1929).

Tampa:
- Tampa-Hillsborough County Public Library (1965).
- University of South Florida Library (1962).
- University of Tampa, Merl Kelce Library (1953).

Winter Park: Rollins College, Mills Memorial Library (1909).

GEORGIA

Albany: Albany-Dougherty Public Library (1964).
Americus: Georgia Southwestern College, James Earl Carter Library (1966).
Athens:
- University of Georgia Libraries (1907)-REGIONAL.
- University of Georgia, School of Law Library (1979).

Atlanta:
- Atlanta Public Library (1880).
- Atlanta University, Trevor Arnett Library (1962).
- Emory University, Robert W. Woodruff Library (1928).
- Emory University, School of Law Library (1968).
- Georgia Institute of Technology Library (1963).
- Georgia State Library (unknown).
- Georgia State University, William Russell Pullen Library (1970).

Augusta: Augusta College, Reese Library (1962).
Brunswick: Brunswick-Glynn County Regional Library (1965).
Carrollton: West Georgia College Library (1962).
Columbus: Columbus College, Simon Schwob Memorial Library (1975).
Dahlonega: North Georgia College, Stewart Library (1939).
Dalton: Dalton Junior College Library (1978).
Decatur: DeKalb Community College-South Campus, Learning Resources Center (1973).
Macon:
- Mercer University, Stetson Memorial Library (1964).
- Mercer University, Walter F. George School of Law Library (1978).

Marietta: Kennesaw College, Memorial Library (1968).
Milledgeville: Georgia College at Milledgeville, Ina Dillard Russell Library (1950).
Mount Berry: Berry College, Memorial Library (1970).
Savannah: Savannah Public and Chatham-Effingham-Liberty Regional Library (1857).
Statesboro: Georgia Southern College Library (1939).
Valdosta: Valdosta State College Library (1956).

GUAM

Agana:
- Nieves M. Flores Memorial Library (1962).
- University of Guam, Robert F. Kennedy Memorial Library (1978).

HAWAII

Hilo: University of Hawaii, Hilo Campus Library (1962).
Honolulu:
- Hawaii Medical Library, Inc. (1968).
- Hawaii State Library (1929).
- Municipal Reference Library of the City and County of Honolulu (1965).
- Supreme Court Law Library (1973).
- University of Hawaii Library (1907)-REGIONAL.
- University of Hawaii, School of Law Library (1978).

Laie: Brigham Young University, Hawaii Campus, Joseph F. Smith Library (1964).
Lihue: Kauai Public Library (1967).
Pearl City: Leeward Community College Library (1967).
Wailuku: Maui Public Library (1962).

IDAHO

Boise:
- Boise Public Library and Information Center (1929).
- Boise State University Library (1966).
- Idaho State Law Library (unknown).
- Idaho State Library (1971).

Caldwell: College of Idaho, Terteling Library (1930).
Moscow:
- University of Idaho, College of Law Library (1978).
- University of Idaho Library (1907)-REGIONAL.

Pocatello: Idaho State University Library (1908).
Rexburg: Ricks College, David O. McKay Library (1946).
Twin Falls: College of Southern Idaho Library (1970).

ILLINOIS

Bloomington: Illinois Wesleyan University Libraries (1964).
Carbondale:
- Southern Illinois University, Morris Library (1932).
- Southern Illinois University, School of Law Library (1978).

Carlinville: Blackburn College, Lumpkin Library (1954).
Carterville: Shawnee Library System (1971).
Champaign: University of Illinois, College of Law Library (1965).
Charleston: Eastern Illinois University, Booth Library (1962).
Chicago:
- Chicago Public Library (1876).
- Chicago State University, Paul and Emily Douglas Library (1954).
- DePaul University, Lincoln Park Campus Library (1975).
- DePaul University, School of Law Library (1979).
- Field Museum of Natural History Library (1963).
- Illinois Institute of Technology, Chicago-Kent Law Library (1978).
- John Crerar Library (1909).
- Loyola University of Chicago, E. M. Cudahy Memorial Library (1966).
- Loyola University, School of Law Library (1979).
- Northeastern Illinois University Library (1961).

Northwestern University, School of Law Library (1978).
University of Chicago, Law Library (1964).
University of Chicago Library (1897).
University of Illinois at Chicago Circle Library (1957).
William J. Campbell Library of the U.S. Courts (1979).
Decatur: Decatur Public Library (1954).
De Kalb: Northern Illinois University, Founders' Memorial Library (1960).
Edwardsville: Southern Illinois University, Lovejoy Memorial Library (1959).
Elsah: Principia College, Marshall Brooks Library (1957).
Evanston: Northwestern University Library (1876).
Freeport: Freeport Public Library (1905).
Galesburg: Galesburg Public Library (1896).
Glen Ellyn: Lewis University, College of Law Library (1978).
Jacksonville: MacMurray College, Henry Pfeiffer Library (1957).
Kankakee: Olivet Nazarene College, Benner Library and Resources Center (1946).
Lake Forest: Lake Forest College, Donnelley Library (1962).
Lebanon: McKendree College, Holman Library (1968).
Lisle: Illinois Benedictine College, Theodore F. Lownik Library (1911).
Lockport: Lewis University Library (1952).
Macomb: Western Illinois University, Memorial Library (1962).
Moline: Black Hawk College, Learning Resources Center (1970).
Monmouth: Monmouth College Library (1860).
Morton Grove: Oakton Community College Library (1976).
Mt. Carmel: Wabash Valley College, Bauer Media Center (1975).
Mt. Prospect: Mt. Prospect Public Library (1977).
Normal: Illinois State University, Milner Library (1877).
Oak Park: Oak Park Public Library (1963).
Oglesby: Illinois Valley Community College, Jacobs Memorial Library (1976).
Palos Hills: Moraine Valley Community College Library (1972).
Park Forest South: Governors' State University Library (1974).
Peoria:
Bradley University, Cullom Davis Library (1963).
Peoria Public Library (1883).
River Forest: Rosary College Library (1966).
Rockford: Rockford Public Library (unknown).
Springfield: Illinois State Library (unknown)–REGIONAL.
Urbana: University of Illinois Library (1907).
Wheaton: Wheaton College Library (1964).
Woodstock: Woodstock Public Library (1963).

INDIANA

Anderson: Anderson College, Charles E. Wilson Library (1959).
Bloomington:
Indiana University Library (1881).
Indiana University, School of Law Library (1978).
Crawfordsville: Wabash College, Lilly Library (1906).
Evansville:
Evansville and Vanderburgh County Public Library (1928).
Indiana State University, Evansville Campus Library (1969).
Fort Wayne:
Indiana-Purdue Universities, Regional Campus Library (1965).
Public Library of Fort Wayne and Allen County (1896).
Franklin: Franklin College Library (1976).
Gary:
Gary Public Library (1943).
Indiana University, Northwest Campus Library (1966).
Greencastle: De Pauw University, Roy O. West Library (1879).
Hammond: Hammond Public Library (1964).
Hanover: Hanover College Library (1892).
Huntington: Huntington College, Loew-Alumni Library (1964).
Indianapolis:
Butler University (1965).
Indianapolis-Marion County Public Library (1906).
Indiana State Library (unknown)–REGIONAL.
Indiana Supreme Court Law Library (1975).
Indiana University, School of Law Library (1967).
Kokomo: Indiana University, Kokomo Regional Campus Library (1969).
Lafayette: Purdue University Libraries and Audio-Visual Center (1907).
Muncie:
Ball State University Library (1959).
Muncie Public Library (1906).
New Albany: Indiana University, Southeastern Campus Library (1965).
Notre Dame: University of Notre Dame, Memorial Library (1883).
Rensselaer: St. Joseph's College Library (1964).
Richmond:
Earlham College, Lilly Library (1964).
Morrison-Reeves Library (1906).
South Bend: Indiana University at South Bend Library (1965).
Terre Haute: Indiana State University, Cunningham Memorial Library (1906).
Valparaiso:
Valparaiso University, Moellering Memorial Library (1930).
Valparaiso University, School of Law Library (1978).

IOWA

Ames: Iowa State University of Science and Technology Library (1907).
Cedar Falls: University of Northern Iowa Library (1946).
Council Bluffs:
Free Public Library (1885).
Iowa Western Community College, Herbert Hoover Media Library (1972).
Davenport: Davenport Public Library (1973).
Des Moines:
Drake University, Cowles Library (1966).
Drake University Law Library (1972).
Public Library of Des Moines (1888).
State Library Commission of Iowa (unknown).
Dubuque:
Carnegie-Stout Public Library (unknown).
Loras College, Wahlert Memorial Library (1967).
Fayette: Upper Iowa College, Henderson-Wilder Library (1974).
Grinnell: Grinnell College Library (1874).
Iowa City:
University of Iowa, College of Law Library (1968).
University of Iowa Libraries (1884)–REGIONAL.
Lamoni: Graceland College, Frederick Madison Smith Library (1927).
Mason City: North Iowa Area Community College Library (1976).
Mount Vernon: Cornell College, Russell D. Cole Library (1896).
Orange City: Northwestern College, Ramaker Library (1970).
Sioux City: Sioux City Public Library (1894).

KANSAS

Atchison: Benedictine College, North Campus Library (1965).
Baldwin City: Baker University Library (1908).
Colby: Colby Community Junior College, H. F. Davis Memorial Library (1968).
Emporia: Emporia State University, William Allen White Library (1909).
Hays: Fort Hays State University, Forsyth Library (1926).
Hutchinson: Hutchinson Public Library (1963).
Lawrence:
University of Kansas, School of Law Library (1971).

University of Kansas, Watson Library (1869)–REGIONAL.
Manhattan: Kansas State University, Farrell Library (1907).
Pittsburg: Pittsburg State University Library (1952).
Salina: Kansas Wesleyan University, Memorial Library (1930).
Shawnee Mission: Johnson County Library (1979).
Topeka:
Kansas State Historical Society Library (1877).
Kansas State Library (unknown).
Kansas Supreme Court Law Library (1975).
Washburn University of Topeka, Law Library (1971).
Wichita: Wichita State University Library (1901).

KENTUCKY

Ashland: Ashland Public Library (1946).
Barbourville: Union College, Abigail E. Weeks Memorial Library (1958).
Bowling Green: Western Kentucky University, Helm-Cravens Graduate Center and Library (1934).
Covington: Thomas More College Library (1970).
Danville: Centre College, Grace Doherty Library (1884).
Frankfort:
Kentucky Department of Libraries (1967).
Kentucky State Law Library (unknown).
Kentucky State University, Blazer Library (1972).
Highland Heights: Northern Kentucky University, W. Frank Steely Library (1973).
Hopkinsville: Hopkinsville Community College Library (1976).
Lexington:
University of Kentucky, Law Library (1968).
University of Kentucky Libraries (1907)–REGIONAL.
Louisville:
Louisville Free Public Library (1904).
University of Louisville, Belknap Campus Library (1925).
University of Louisville, School of Law Library (1975).
Morehead: Morehead State University, Johnson Camden Library (1955).
Murray: Murray State University Library (1924).
Owensboro: Kentucky Wesleyan College Library (1966).
Richmond: Eastern Kentucky University, John Grant Crabbe Library (1966).

LOUISIANA

Baton Rouge:
Louisiana State Library (1976).
Louisiana State University, School of Law Library (1929).
Louisiana State University Library (1907)–REGIONAL.
Southern University Library (1952).
Eunice: Louisiana State University at Eunice, LeDoux Library (1969).
Hammond: Southeastern Louisiana University, Sims Memorial Library (1966).
Lafayette: University of Southwestern Louisiana Libraries (1938).
Lake Charles: McNeese State University, Lether E. Frazar Memorial Library (1941).
Monroe: Northeast Louisiana University, Sandel Library (1963).
Natchitoches: Northwestern State University, Watson Library (1887).
New Orleans:
Isaac Delgado College, Moss Memorial Library (1968).
Law Library of Louisiana (unknown).
Loyola University Library (1942).
Loyola University, School of Law Library (1978).
New Orleans Public Library (1883).
Southern University in New Orleans Library (1962).
Tulane University, Howard-Tilton Memorial Library (1942).
Tulane University, Law Library (1976).
University of New Orleans Library (1963).
U.S. Court of Appeals, Fifth Circuit Library (1973).
Pineville: Louisiana College, Richard W. Norton Memorial Library (1969).
Ruston: Louisiana Technical University Library (1896)–REGIONAL.
Shreveport:
Louisiana State University at Shreveport Library (1967).
Shreve Memorial Library (1923).
Thibodaux: Nicholls State University Library (1962).

MAINE

Augusta:
Maine Law and Legislative Reference Library (1973).
Maine State Library (unknown).
Bangor: Bangor Public Library (1884).
Brunswick: Bowdoin College Library (1884).
Castine: Maine Maritime Academy, Nutting Memorial Library (1969).
Lewiston: Bates College Library (1883).
Orono: University of Maine, Raymond H. Fogler Library (1907)–REGIONAL.
Portland:
Portland Public Library (1884).
University of Maine, School of Law Library (1964).
Presque Isle: University of Maine at Presque Isle Library (1979).
Springvale: Nasson College Library (1961).
Waterville: Colby College, Miller Library (1884).

MARYLAND

Annapolis:
Maryland State Law Library (unknown).
U.S. Naval Academy, Nimitz Library (1895).
Baltimore:
Enoch Pratt Free Library (1887).
Johns Hopkins University, Milton S. Eisenhower Library (1882).
Morgan State College, Soper Library (1940).
University of Baltimore, Langsdale Library (1973).
University of Maryland, Baltimore County Library (1971).
University of Maryland, School of Law Library (1969).
Bel Air: Harford Community College Library (1967).
Beltsville: Department of Agriculture, National Agricultural Library (1895).
Bethesda: Department of Health, Education, and Welfare, National Library of Medicine (1978).
Chestertown: Washington College, Chester M. Miller Library (1891).
College Park: University of Maryland, McKeldin Library (1925)–REGIONAL.
Cumberland: Allegany Community College Library (1974).
Frostburg: Frostburg State College Library (1967).
Patuxent River: U.S. Naval Air Station Library (1968).
Rockville: Montgomery County Department of Public Libraries (1951).
Salisbury: Salisbury State College, Blackwell Library (1965).
Towson: Goucher College, Julia Roger Library (1966).
Westminster: Western Maryland College, Hoover Library (1886).

MASSACHUSETTS

Amherst:
Amherst College Library (1884).
University of Massachusetts Library (1907).
Belmont: Belmont Memorial Library (1968).
Boston:
Boston Athenaeum Library (unknown).
Boston Public Library (1859)–REGIONAL.

Boston University, School of Law, Pappas Library (1979).
Northeastern University Libraries (1962).
State Library of Massachusetts (unknown).
Supreme Judicial Court, Social Law Library (1979).
U.S. Court of Appeals, First Circuit Library (1978).
Brookline: Public Library of Brookline (1925).
Cambridge:
Harvard College Library (1860).
Massachusetts Institute of Technology Libraries (1946).
Middlesex County Law Library (1978).
Chestnut Hill: Boston College, Bapst Library (1963).
Chicopee: Our Lady of the Elms College Library (1969).
Lowell: University of Lowell, Alumni/Lydon Library (1952).
Lynn: Lynn Public Library (1953).
Marlborough: Marlborough Public Library (1971).
Medford: Tufts University Library (1899).
Milton: Curry College Library (1972).
New Bedford: New Bedford Free Public Library (1858).
Newton Centre: Boston College, School of Law Library (1979).
North Dartmouth: Southeastern Massachusetts University Library (1965).
North Easton: Stonehill College, Cushing-Martin Library (1962).
Springfield:
Springfield City Library (1966).
Western New England College, School of Law Library (1978).
Waltham: Brandeis University Library (1965).
Wellesley: Wellesley College Library (1943).
Wenham: Gordon College, Winn Library (1963).
Williamstown: Williams College Library (unknown).
Worcester:
American Antiquarian Society Library (1814).
University of Massachusetts, Medical Center Library (1972).
Worcester Public Library (1859).

MICHIGAN

Albion: Albion College, Stockwell Memorial Library (1966).
Allendale: Grand Valley State College Library (1963).
Alma: Alma College, Monteith Library (1963).
Ann Arbor:
Great Lakes Basin Commission Library (1971).
University of Michigan, Harlan Hatcher Library (1884).
University of Michigan, School of Law Library (1978).
Benton Harbor: Benton Harbor Public Library (1907).
Bloomfield Hills: Cranbrook Institute of Science Library (1940).
Dearborn:
Henry Ford Centennial Library (1969).
Henry Ford Community College Library (1957).
Detroit:
Detroit College of Law Library (1979).
Detroit Public Library (1868)–REGIONAL.
Marygrove College Library (1965).
Mercy College of Detroit Library (1965).
University of Detroit Library (1884).
University of Detroit, School of Law Library
Wayne State University, G. Flint Purdy Library (1937).
Wayne State University, Law Library (1971).
Dowagiac: Southwestern Michigan College, Mathews Library (1971).
East Lansing: Michigan State University Library (1907).
Escanaba: Michigan State Library, Upper Peninsula Branch (1964).
Farmington: Oakland Community College, Martin Luther King Learning Resources Center, (1968).
Flint:
Flint Public Library (1967).
University of Michigan at Flint Library (1959).
Grand Rapids:
Calvin College Library (1967).
Grand Rapids Public Library (1876).
Houghton: Michigan Technological University Library (1876).
Jackson: Jackson Public Library (1965).
Kalamazoo:
Kalamazoo Public Library (1907).
Western Michigan University Library (1963).
Lansing:
Michigan State Library (unknown)–REGIONAL.
Thomas M. Cooley Law School Library (1978).
Livonia: Schoolcraft College Library (1962).
Marquette: Northern Michigan University, Olsen Library (1963).
Monroe: Monroe County Library System (1974).
Mt. Clemens: Macomb County Library (1968).
Mt. Pleasant: Central Michigan University Library (1958).
Muskegon: Hackley Public Library (1894).
Olivet: Olivet College Library (1974).
Petoskey: North Central Michigan College Library (1962).
Port Huron: Saint Clair County Library (1876).
Rochester: Oakland University, Kresge Library (1964).
Saginaw: Hoyt Public Library (1890).
Traverse City: Northwestern Michigan College, Mark Osterlin Library (1964).
University Center: Delta College Library (1963).
Warren: Warren Public Library, Arthur J. Miller Branch (1973).
Wayne: Wayne Oakland Federated Library System (1957).
Ypsilanti: Eastern Michigan University Library (1965).

MINNESOTA

Bemidji: Bemidji State College, A. C. Clark Library (1963).
Collegeville: St. John's University, Alcuin Library (1954).
Duluth: Duluth Public Library (1909).
Mankato: Mankato State College, Memorial Library (1962).
Minneapolis:
Anoka County Library (1971).
Hennepin County Libraries (1971).
Minneapolis Public Library (1893).
University of Minnesota, School of Law Library (1978).
University of Minnesota, Wilson Library (1907)–REGIONAL.
Moorhead: Moorhead State College Library (1956).
Morris: University of Minnesota at Morris Library (1963).
Northfield:
Carleton College Library (1930).
St. Olaf College, Rolvaag Memorial Library (1930).
St. Cloud: St. Cloud State College Library (1962).
St. Paul:
Hamline University, School of Law Library (1978).
Minnesota Historical Society Library (1867).
Minnesota State Law Library (unknown).
St. Paul Public Library (1914).
University of Minnesota, St. Paul Campus Library (1974).
William Mitchell College of Law Library (1979).
Saint Peter: Gustavus Adolphus College Library (1941).
Stillwater: Stillwater Public Library (1893).
Willmar: Crow River Regional Library (1958).
Winona: Winona State University, Maxwell Library (1969).

MISSISSIPPI

Cleveland: Delta State University, W. B. Roberts Library (1975).
Clinton: Mississippi College, School of Law Library (1977).
Columbus: Mississippi State University for Women, John Clayton Fant Memorial Library (1929).
Hattiesburg: University of Southern Mississippi, Joe Cook Memorial Library (1935).
Jackson:
Jackson State University, Henry Thomas Sampson Library (1968).
Millsaps College, Millsaps-Wilson Library (1963).
Mississippi Library Commission (1947).

Mississippi State Law Library (unknown).
Lorman: Alcorn State University Library (1970).
Mississippi State: Mississippi State University, Mitchell Memorial Library (1907).
University:
University of Mississippi Library (1833)–REGIONAL.
University of Mississippi, School of Law Library (1967).

MISSOURI

Cape Girardeau: Southeast Missouri State University, Kent Library (1916).
Columbia:
University of Missouri at Columbia Library (1862).
University of Missouri at Columbia, School of Law Library (1978).
Fayette: Central Methodist College, George M. Smiley Library (1962).
Fulton: Westminster College, Reeves Library (1875).
Jefferson City:
Lincoln University, Inman E. Page Library (1944).
Missouri State Library (1963).
Missouri Supreme Court Library (unknown).
Joplin: Missouri Southern State College Library (1966).
Kansas City:
Kansas City Public Library (1881).
Rockhurst College, Greenlease Library (1917).
University of Missouri at Kansas City, General Library (1938).
University of Missouri at Kansas City, Leon E. Bloch School of Law Library (1978).
Kirksville: Northeast Missouri State University, Pickler Memorial Library (1966).
Liberty: William Jewell College, Charles F. Curry Library (1900).
Rolla: University of Missouri at Rolla Library (1907).
St. Charles: Lindenwood College, Margaret Leggat Butler Library (1973).
St. Joseph: St. Joseph Public Library (1891).
St. Louis:
Maryville College Library (1976).
St. Louis County Library (1970).
St. Louis Public Library (1866).
St. Louis University, Law Library (1967).
St. Louis University, Pius XII Memorial Library (1966).
University of Missouri at St. Louis, Thomas Jefferson Library (1966).
U.S. Court of Appeals, Eighth Circuit Library (1972).
Washington University, John M. Olin Library (1906).
Washington University, School of Law Library (1978).
Springfield:
Drury College, Walker Library (1874).
Southwest Missouri State University Library (1963).
Warrensburg: Central Missouri State University, Ward Edwards Library (1914).

MONTANA

Billings: Eastern Montana College Library (1924).
Bozeman: Montana State University Library (1907).
Butte: Montana College of Mineral Science and Technology Library (1901).
Helena:
Carroll College Library (1974).
Montana Historical Society Library (unknown).
Montana State Library (1966).
State Law Library of Montana (1977).
Missoula: University of Montana Library (1909)–REGIONAL.

NEBRASKA

Blair: Dana College, Dana-LIFE Library (1924).
Crete: Doane College, Perkins Library (1944).
Fremont: Midland Lutheran College Library (1924).
Kearney: Kearney State College, Calvin T. Ryan Library (1962).
Lincoln:
Nebraska Publications Clearinghouse, Nebraska Library Commission (1972)–REGIONAL.
Nebraska State Library (unknown).
University of Nebraska at Lincoln, D. L. Love Memorial Library (1907)–JOINT REGIONAL.
Omaha:
Creighton University, Alumni Memorial Library (1964).
Omaha Public Library, W. Dale Clark Library (1880).
University of Nebraska at Omaha, University Library (1939).
Scottsbluff: Scottsbluff Public Library (1925).
Wayne: Wayne State College, U.S. Connecticut Library (1970).

NEVADA

Carson City:
Nevada State Library (unknown).
Nevada Supreme Court Library (1973).
Las Vegas:
Clark County Library District (1974).
University of Nevada, James Dickinson Library (1959).
Reno:
National Judicial College, Law Library (1979).
Nevada State Historical Society Library (1974).
University of Nevada Library (1907)–REGIONAL

NEW HAMPSHIRE

Concord:
Franklin Pierce Law Center Library (1973).
New Hampshire State Library (unknown).
Durham: University of New Hampshire Library (1907).
Hanover: Dartmouth College Library (1884).
Henniker: New England College Library (1966).
Manchester:
Manchester City Library (1884).
New Hampshire College, H. A. B. Shapiro Memorial Library (1976).
St. Anselm's College, Geisel Library (1963).
Nashua: Nashua Public Library (1971).

NEW JERSEY

Bayonne: Bayonne Free Public Library (1909).
Bloomfield: Free Public Library of Bloomfield (1965).
Bridgeton: Cumberland County Library (1966).
Camden:
Rutgers University, Camden Library (1966).
Rutgers University, School of Law Library (1979).
Convent Station: College of St. Elizabeth, Mahoney Library (1938).
Dover: County College of Morris, Library Learning Resources Center (1975).
East Brunswick: East Brunswick Public Library (1977).
East Orange: East Orange Public Library (1966).
Elizabeth: Free Public Library of Elizabeth (1895).
Glassboro: Glassboro State College, Savitz Learning Resource Center (1963).
Hackensack: Johnson Free Public Library (1966).
Irvington: Free Public Library of Irvington (1966).
Jersey City:
Free City Public Library (1879).
Jersey City State College, Forrest A. Irwin Library (1963).

Lawrenceville: Rider College Library (1975).
Madison: Drew University, Rose Memorial Library (1939).
Mahwah: Ramapo College Library (1971).
Mount Holly: Burlington County Library (1966).
New Brunswick:
New Brunswick Free Public Library (1908).
Rutgers University Library (1907).
Newark:
Newark Public Library (1906)–REGIONAL.
Rutgers, The State University, John Cotton Dana Library (1966).
Rutgers University, School of Law Library (1979).
Passaic: Passaic Public Library (1964).
Phillipsburg: Phillipsburg Free Public Library (1976).
Plainfield: Plainfield Public Library (1971).
Pomona: Stockton State College Library (1972).
Princeton: Princeton University Library (1884).
Rutherford: Fairleigh Dickinson University Library (1953).
Shrewsbury: Monmouth County Library (1968).
South Orange: Seton Hall University, McLaughlin Library (1947).
Teaneck: Fairleigh Dickinson University, Teaneck Campus Library (1963).
Toms River: Ocean County College, Learning Resources Center (1966).
Trenton:
New Jersey State Library, Law and Reference Bureau (unknown).
Trenton Free Public Library (1902).
Union: Kean College of New Jersey, Nancy Thompson Library (1973).
Upper Montclair: Montclair State College, Harry S. Sprague Library (1967).
Wayne: Wayne Public Library (1972).
West Long Branch: Monmouth College, Guggenheim Memorial Library (1963).
Woodbridge: Free Public Library of Woodbridge (1965).

NEW MEXICO

Albuquerque:
University of New Mexico, Medical Center Library (1973).
University of New Mexico, School of Law Library (1973).
University of New Mexico, Zimmerman Library (1896)–REGIONAL.
Hobbs: New Mexico Junior College, Pannell Library (1969).
Las Cruces: New Mexico State University Library (1907).
Las Vegas: New Mexico Highlands University, Donnelly Library (1913).
Portales: Eastern New Mexico University Library (1962).
Santa Fe:
New Mexico State Library (1960)–REGIONAL.
Supreme Court Law Library (unknown).
Silver City: Western New Mexico University, Miller Library (1972).

NEW YORK

Albany:
New York State Library (unknown)–REGIONAL.
State University of New York at Albany, University Library (1964).
Auburn: Seymour Library (1972).
Bayside: Queensborough Community College Library (1972).
Binghamton: State University of New York at Binghamton, University Library (1962).
Brockport: State University of New York at Brockport, Drake Memorial Library (1967).
Bronx:
Fordham University Library (1937).
Herbert H. Lehman College Library (1967).
New York Public Library, Mott Haven Branch (1973).
State University of New York, Maritime College Library (1947).
Brooklyn:
Brooklyn College Library (1936).
Brooklyn Law School Library (1974).
Brooklyn Public Library (1908).
Polytechnic Institute of Brooklyn Libraries (1963).
Pratt Institute Library (1891).
State University of New York, Downstate Medical Research Library (1958).
Buffalo:
Buffalo and Erie County Public Library (1895).
State University of New York at Buffalo, School of Law, Charles B. Sears Law Library (1978).
State University of New York at Buffalo, Lockwood Memorial Library (1963).
Canton: St. Lawrence University, Owen D. Young Library (1920).
Cheektowago: Cheektowago Public Library (1978).
Corning: Corning Community College, Arthur A. Houghton, Jr. Library (1963).
Cortland: State University of New York at Cortland, Memorial Library (1964).
Delhi: State University Agricultural and Technical College Library (1970).
East Islip: East Islip Public Library (1973).
Elmira: Elmira College, Gannett-Tripp Learning Center (1956).
Farmingdale: State University of New York at Farmington Library (1917).
Flushing:
Cathedral College Library (1971).
Queens College, Paul Klapper Library (1939).
Garden City: Adelphi University Library (1966).
Geneseo: State University of New York at Geneseo, Milne Library (1967).
Greenvale: Long Island University, B. Davis Schwartz Memorial Library (1964).
Hamilton: Colgate University Library (1902).
Hempstead:
Hofstra University Library (1964).
Hofstra University, School of Law Library (1979).
Ithaca:
Cornell University Libraries (1907).
Cornell University, School of Law Library (1978).
New York State College of Agriculture and Home Economics, Albert R. Mann Library (1943).
Jamaica:
Queens Borough Public Library (1926).
St. John's University Library (1956).
St. John's University, School of Law Library (1978).
Kings Point: U.S. Merchant Marine Academy, Academy Library (1962).
Mount Vernon: Mount Vernon Public Library (1962).
New Paltz: State University College at New Paltz, Sojourner Truth Library (1965).
New York City:
City University of New York, City College Library (1884).
Columbia University Libraries (1882).
Cooper Union for the Advancement of Science and Arts Library (1930).
Medical Library Center of New York (1976).
New York Law Institute Library (1909).
New York Public Library, Astor Branch (1907).
New York Public Library, Lenox Branch (1884).
New York University, Law Library (1973).
New York University Libraries (1967).
The College of Insurance Library (1965).
U.S. Court of Appeals, Second Circuit Library (1976).
Newburgh: Newburgh Free Library (1909).
Niagara Falls: Niagara Falls Public Library (1976).
Oakdale: Dowling College (1965).

Oneonta: State University College at Oneonta, James M. Milne Library (1966).
Oswego: State University of New York at Oswego, Penfield Library (1966).
Plattsburgh: State University College at Plattsburgh, Benjamin F. Feinberg Library (1967).
Potsdam:
Clarkson College of Technology Library (1938).
State University College at Potsdam, Frederick W. Crumb Memorial Library (1964).
Poughkeepsie: Vassar College Library (1943).
Purchase: State University of New York at Purchase Library (1969).
Rochester:
Rochester Public Library (1963).
University of Rochester Library (1880).
St. Bonaventure: St. Bonaventure University, Friedsam Memorial Library (1938).
Saratoga Springs: Skidmore College Library (1964).
Schenectady: Union College, Schaffer Library (1901).
Southampton: Southampton College Library (1973).
Staten Island: Wagner College, Horrmann Library, Grymes Hill (1953).
Stony Brook: State University of New York at Stony Brook, Main Library (1963).
Syracuse:
Onondaga County Public Library (1978).
Syracuse University Library (1878).
Syracuse University, William C. Ruger Law Library (1978).
Troy: Troy Public Library (1869).
Uniondale: Nassau Library System (1965).
Utica:
Utica Public Library (1885).
State University College at Utica/Rome Library (1977).
West Point: U.S. Military Academy Library (unknown).
White Plains: Pace University, School of Law Library (1978).
Yonkers:
Sarah Lawrence College Library (1969).
Yonkers Public Library (1910).
Yorktown Heights: Mercy College Library (1976).

NORTH CAROLINA

Asheville: University of North Carolina at Asheville, D. Hiden Ramsey Library (1965).
Boiling Springs: Gardner-Webb College Library (1974).
Boone: Appalachian State University Library (1963).
Buies Creek: Campbell College, Carrie Rich Memorial Library (1965).
Chapel Hill:
University of North Carolina at Chapel Hill Library (1884)–REGIONAL.
University of North Carolina at Chapel Hill, School of Law Library (1978).
Charlotte:
Public Library of Charlotte and Mecklenburg County (1964).
Queens College, Everett Library (1927).
University of North Carolina at Charlotte, Atkins Library (1964).
Cullowhee: Western Carolina University, Hunter Library (1953).
Davidson: Davidson College Library (1893).
Durham:
Duke University, School of Law Library (1978).
Duke University, William R. Perkins Library (1890).
North Carolina Central University, James E. Shepard Memorial Library (1973).
Elon College: Iris Holt McEwen Library (1971).
Fayetteville: Fayetteville State University, Charles W. Chestnutt Library (1971).
Greensboro:
North Carolina Agricultural and Technical State University, F. D. Bluford Library (1937).
University of North Carolina at Greensboro, Walter Clinton Jackson Library (1963).
Greenville: East Carolina University Library (1951).
Laurinburg: St. Andrews Presbyterian College, DeTamble Library (1969).
Lexington: Davidson County Public Library (1971).
Mount Olive: Mount Olive College, Moye Library (1971).
Murfreesboro: Chowan College, Whitaker Library (1963).
Pembroke: Pembroke State University, Mary H. Livermore Library (1956).
Raleigh:
Department of Cultural Resources, Division of State Library (unknown).
North Carolina State University, D. H. Hill Library (1923).
North Carolina Supreme Court Library (1972).
Wake County Public Library (1969).
Rocky Mount: North Carolina Wesleyan College Library (1969).
Salisbury: Catawba College Library (1925).
Wilmington: University of North Carolina at Wilmington, William M. Randall Library (1965).
Wilson: Atlantic Christian College, Clarence L. Hardy Library (1930).
Winston-Salem:
Forsyth County Public Library (1954).
Wake Forest University, Z. Smith Reynolds Library (1902).

NORTH DAKOTA

Bismarck:
North Dakota State Historical Society Library (1907).
North Dakota State Library (1971).
North Dakota Supreme Court Law Library (unknown).
Veterans' Memorial Public Library (1967).
Dickinson: Dickinson State College, Stoxen Library (1968).
Fargo:
Fargo Public Library (1964).
North Dakota State University Library (1907)–REGIONAL, in cooperation with University of North Dakota, Chester Fritz Library.
Grand Forks: University of North Dakota, Chester Fritz Library (1890).
Minot: Minot State College, Memorial Library (1925).
Valley City: Valley City State College Library (1913).

OHIO

Ada: Ohio Northern University, J. P. Taggart Law Library (1965).
Akron:
Akron-Summit Public Library (1952).
University of Akron, Bierce Library (1963).
University of Akron, C. Blake McDowell Law Center, School of Law Library (1978).
Alliance: Mount Union College Library (1888).
Ashland: Ashland College Library (1938).
Athens: Ohio University Library (1886).
Batavia: University of Cincinnati at Batavia, Clermont General and Technical College Library (1973).
Bluffton: Bluffton College, Musselman Library (1951).
Bowling Green: Bowling Green State University Library (1933).
Canton: Malone College, Everett L. Cattell Library (1970).
Chardon: Geauga County Public Library (1971).
Cincinnati:
Public Library of Cincinnati and Hamilton County (1884).
University of Cincinnati, Central Library (1929).
University of Cincinnati, College of Law, Marx Law Library (1978).
Cleveland:
Case Western Reserve University, Freiberger Library (1913).

Case Western Reserve University, School of Law Library (1979).
Cleveland Heights-University Heights Public Library (1970).
Cleveland Public Library (1886).
Cleveland State University, Cleveland-Marshall College of Law, Joseph W. Bartunek III Law Library (1978).
Cleveland State University Library (1966).
John Carroll University, Grasselli Library (1963).
Municipal Reference Library (1970).

Columbus:
Capital University Library (1968).
Ohio State Library (unknown)-REGIONAL.
Ohio State University Libraries (1907).
Ohio Supreme Court Law Library (1973).
The Public Library of Columbus and Franklin County (1885).

Dayton:
Dayton and Montgomery County Public Library (1909).
University of Dayton, Albert Emanuel Library (1969).
Wright State University Library (1965).

Delaware: Ohio Wesleyan University, L. A. Beeghly Library (1845).
Elyria: Elyria Public Library (1966).
Findlay: Findlay College, Shafer Library (1969).
Gambier: Kenyon College Library (1873).
Granville: Denison University Library (1884).
Hiram: Hiram College, Teachout-Price Memorial Library (1874).
Kent: Kent State University Libraries (1962).
Marietta: Marietta College, Dawes Memorial Library (1884).
Middletown: Miami University at Middletown, Gardner-Harvey Library (1970).
New Concord: Muskingum College Library (1966).
Oberlin: Oberlin College Library (1858).
Oxford: Miami University at Oxford, Alumni Library (1909).
Portsmouth: Portsmouth Public Library (unknown).
Rio Grande: Rio Grande College, Jeanette Albiez Davis Library (1966).
Springfield: Warder Public Library (1884).

Steubenville:
Public Library of Steubenville and Jefferson County (1950).
The College of Steubenville, Starvaggi Memorial Library (1971).

Tiffin: Heidelberg College, Beeghly Library (1964).

Toledo:
Toledo-Lucas County Public Library (1884).
University of Toledo Library (1963).

Westerville: Otterbein College Library (1967).
Wooster: College of Wooster, Andrews Library (1966).

Youngstown:
Public Library of Youngstown and Mahoning County (1923).
Youngstown State University, William F. Maag Library (1971).

OKLAHOMA

Ada: East Central University, Linscheid Library (1914).
Alva: Northwestern Oklahoma State University Library (1907).
Bartlesville: U.S. Department of Energy, Bartlesville Energy Research Center Library (1962).
Bethany: Bethany Nazarene College, R. T. Williams Library (1971).
Durant: Southeastern Oklahoma State University Library (1929).
Edmond: Central State University Library (1934).
Enid: Public Library of Enid and Garfield County (1908).
Langston: Langston University, G. Lamar Harrison Library (1941).
Muskogee: Muskogee Public Library (1971).

Norman:
University of Oklahoma Library (1893).
University of Oklahoma, School of Law Library (1978).

Oklahoma City:
Metropolitan Library System (1974).
Oklahoma City University Library (1963).
Oklahoma Department of Libraries (1893)-REGIONAL.

Shawnee: Oklahoma Baptist University Library (1933).
Stillwater: Oklahoma State University Library (1907).
Tahlequah: Northeastern Oklahoma State University, John Vaughan Library (1923).

Tulsa:
Tulsa City-County Library (1963).
University of Tulsa, College of Law Library (1979).
University of Tulsa, McFarlin Library (1929).

Weatherford: Southwestern Oklahoma State University, Al Harris Library (1958).

OREGON

Ashland: Southern Oregon State College Library (1953).
Corvallis: Oregon State University Library (1907).
Eugene: University of Oregon Library (1883).
Forest Grove: Pacific University Library (1897).
La Grande: Eastern Oregon College, Walter M. Pierce Library (1954).
McMinnville: Linfield College, Northup Library (1965).
Monmouth: Oregon College of Education Library (1967).

Portland:
Lewis and Clark College, Aubrey R. Watzek Library (1967).
Library Association of Portland (1884).
Portland State University Library (1963)-REGIONAL.
Reed College Library (1912).
U.S. Department of Energy, Bonneville Power Administration Library (1962).

Salem:
Oregon State Library (unknown).
Oregon Supreme Court Library (1974).
Willamette University, College of Law Library (1979).
Willamette University, Main Library (1969).

PENNSYLVANIA

Allentown: Muhlenberg College, Haas Library (1939).
Altoona: Altoona Public Library (1969).
Bethlehem: Lehigh University, Linderman Library (1876).
Blue Bell: Montgomery County Community College, Learning Resources Center (1975).

Carlisle:
Dickinson College, Boyd Lee Spahr Library (1947).
Dickinson College, School of Law, Sheeley-Lee Law Library (1978).

Cheyney: Cheyney State College, Leslie Pickney Hill Library (1967).
Collegeville: Ursinus College, Myrin Library (1963).
Coraopolis: Robert Morris College Library (1978).
Doylestown: Bucks County Free Library (1970).
East Stroudsburg: East Stroudsburg State College, Kemp Library (1966).
Erie: Erie City and County Library (1897).
Greenville: Thiel College, Langenheim Memorial Library (1963).
Harrisburg: State Library of Pennsylvania (unknown)-REGIONAL.
Haverford: Haverford College, Magill Library (1897).
Hazleton: Hazleton Area Public Library (1964).
Indiana: Indiana University of Pennsylvania, Rhodes R. Stabley Library (1962).
Johnstown: Cambria County Library System (1965).
Lancaster: Franklin and Marshall College, Fackenthal Library (1895).
Lewisburg: Bucknell University, Ellen Clarke Bertrand Library (1963).
Mansfield: Mansfield State College Library (1968).

Meadville: Allegheny College, Lawrence Lee Pelletier Library (1907).
MillersvUniversity, School of Law Library (1978).
La Roche College, John J. Wright Library (1974).
University of Pittsburgh, Hillman Library (1910).
University of Pittsburgh, School of Law Library (1979).
U.S. Department of Interior, Bureau of Mines Library (1962).
Pottsville: Pottsville Free Public Library (1967).
Reading: Reading Public Library (1901).
Scranton: Scranton Public Library (1895).
Shippensburg: Shippensburg State College, Ezra Lehman Memorial Library (1973).
Slippery Rock: Slippery Rock State College Library (1965).
Swarthmore: Swarthmore College Library (1923).
University Park: Pennsylvania State University Library (1907).
Villanova: Villanova University, Pulling Law Library (1964).
Warren: Warren Library Association (1885).
Washington: Washington and Jefferson College, Memorial Library (1884).
Waynesburg: Waynesburg College Library (1964).
West Chester: West Chester State College, Francis Harvey Green Library (1967).
Wilkes-Barre: King's College, D. Leonard Corgan Library (1949).
Williamsport: Lycoming College Library (1970).
York: York College of Pennsylvania Library (1963).
Youngwood: Westmoreland County Community College, Learning Resources Center (1972).

PUERTO RICO

Mayaguez: University of Puerto Rico, Mayaguez Campus Library (1928).
Ponce:
Catholic University of Puerto Rico, Encarnacion Valdes Library (1966).
Catholic University of Puerto Rico, School of Law Library (1978).
Rio Piedras: University of Puerto Rico, General Library (1928).

RHODE ISLAND

Kingston: University of Rhode Island Library (1907).
Newport: U.S. Naval War College Library (1963).
Providence:
Brown University, John D. Rockefeller, Jr. Library (unknown).
Providence College, Phillips Memorial Library (1969).
Providence Public Library (1884).
Rhode Island College, James P. Adams Library (1965).
Rhode Island State Library (before 1895).
Warwick: Warwick Public Library (1966).
Westerly: Westerly Public Library (1909).
Woonsocket: Woonsocket Harris Public Library (1977).

SOUTH CAROLINA

Charleston:
Baptist College at Charleston, L. Mendel Rivers Library (1967).
The Citadel, Daniel Library (1962).
The College of Charleston, Robert Scott Small Library (1869).
Clemson: Clemson University Library (1893).
Columbia:
Benedict College, Learning Resources Center (1969).
Richland County Public Library (1978).
South Carolina State Library (before 1895).
University of South Carolina, Thomas Cooper Library (1884).
Conway: University of South Carolina, Coastal Carolina College Library (1974).
Due West: Erskine College, McCain Library (1968).
Florence:
Florence County Library (1967).
Francis Marion College, James A. Rogers Library (1970).
Greenville:
Furman University Library (1962).
Greenville County Library (1966).
Greenwood: Lander College, Larry A. Jackson Library (1967).
Orangeburg: South Carolina State College, Miller F. Whittaker Library (1953).
Rock Hill: Winthrop College, Dacus Library (1896).
Spartanburg: Spartanburg County Public Library (1967).

SOUTH DAKOTA

Aberdeen: Northern State College Library (1963).
Brookings: South Dakota State University, H. M. Briggs Library (1889).
Pierre:
South Dakota State Library (1973).
South Dakota Supreme Court Library (1978).
Rapid City:
Rapid City Public Library (1963).
South Dakota School of Mines and Technology (1963).
Sioux Falls:
Augustana College, Mikkelsen Library and Learning Resources Center (1969).
Sioux Falls Public Library (1903).
Spearfish: Black Hills State College Library (1942).
Vermillion: University of South Dakota, I. D. Weeks Library (1889).
Yankton: Yankton College, James Lloyd Library (1904).

TENNESSEE

Bristol: King College, E. W. King Library (1970).
Chattanooga:
Chattanooga-Hamilton County Bicentennial Library (1908).
U.S. Tennessee Valley Authority Technical Library (1976).
Clarksville: Austin Peay State University, Felix G. Woodward Library (1945).
Cleveland: Cleveland State Community College Library (1973).
Columbia: Columbia State Community College, John W. Finney Memorial Library (1973).
Cookeville: Tennessee Technological University, Jere Whitson Memorial Library (1969).
Jackson: Lambuth College, Luther L. Gobbel Library (1967).
Jefferson City: Carson-Newman College Library (1964).
Johnson City: East Tennessee State University, Sherrod Library (1942).
Knoxville:
Knoxville-Knox County Public Library (1973).
University of Tennessee at Knoxville, James D. Hoskins Library (1907).
University of Tennessee at Knoxville, Law Library (1971).
Martin: University of Tennessee at Martin, Paul Meek Library (1957).
Memphis:
Memphis-Shelby County Public Library and Information Center (1896).
Memphis State University, John W. Brister Library (1966).
Murfreesboro: Middle Tennessee State University Library (1912).
Nashville:
Fisk University Library (1965).
Joint University Libraries (1884).
Public Library of Nashville and Davidson County (1884).

Tennessee State Law Library (1976).
Tennessee State Library and Archives (unknown).
Tennessee State University Library (1972).
Vanderbilt University Law Library (1976).
Sewanee: University of the South, Jesse Ball duPont Library (1873).

TEXAS

Abilene:
Abilene Christian University, Margarett and Herman Brown Library (1978).
Hardin-Simmons University, Rupert and Pauline Richardson Library (1940).
Arlington:
Arlington Public Library (1970).
University of Texas at Arlington Library (1963).
Austin:
Texas State Law Library (1972).
Texas State Library (unknown)-REGIONAL.
University of Texas at Austin Library (1884).
University of Texas at Austin, Lyndon B. Johnson School of Public Affairs Library (1966).
University of Texas at Austin, Tarlton Law Library (1965).
Baytown: Lee College Library (1970).
Beaumont: Lamar University, Mary and John Gray Library (1957).
Brownwood: Howard Payne College, Walker Memorial Library (1964).
Canyon: West Texas State University Library (1928).
College Station: Texas Agricultural and Mechanical University Library (1907).
Commerce: East Texas State University Library (1937).
Corpus Christi: Corpus Christi University Library (1976).
Corsicana: Navarro College, Gaston T. Gooch Library (1965).
Dallas:
Bishop College, Zale Library (1966).
Dallas Baptist College Library (1967).
Dallas Public Library (1900).
Southern Methodist University, Fondren Library (1925).
University of Texas Health Science Center Library at Dallas (1975).
Denton: North Texas State University Library (1948).
Edinburg: Pan American University Library (1959).
El Paso:
El Paso Public Library (1906).
University of Texas at El Paso Library (1966).
Fort Worth:
Fort Worth Public Library (1905).
Texas Christian University, Mary Couts Burnett Library (1916).
Galveston: Rosenberg Library (1909).
Houston:
Houston Public Library (1884).
North Harris County College, Learning Resources Center (1974).
Rice University, Fondren Library (1967).
University of Houston Library (1957).
University of Houston, School of Law Library (1979).
Huntsville: Sam Houston State University Library (1949).
Irving: Irving Public Library System (1974).
Kingsville: Texas Arts and Industries University Library (1944).
Lake Jackson: Brazosport College Library (1969).
Laredo: Laredo Junior College, Yeary Library (1970).
Longview: Nicholson Memorial Public Library (1961).
Lubbock:
Texas Tech University Library (1935)-REGIONAL.
Texas Tech University, School of Law Library (1978).
Marshall: Wiley College, Thomas Winston Cole, Sr. Library (1962).
Mesquite: Mesquite Public Library (1975).
Nacogdoches: Stephen F. Austin State University, Steen Library (1965).
Plainview: Wayland Baptist College, Van Howeling Memorial Library (1963).
Richardson: University of Texas at Dallas Library (1972).
San Angelo: Angelo State University Library (1964).
San Antonio:
San Antonio College Library (1972).
San Antonio Public Library, (1899).
St. Mary's University, Academic Library (1964).
Trinity University Library (1964).
University of Texas at San Antonio Library (1973).
San Marcos: Southwest Texas State University Library (1955).
Seguin: Texas Lutheran College, Blumberg Memorial Library (1970).
Sherman: Austin College, Arthur Hopkins Library (1963).
Texarkana: Texarkana Community College, Palmer Memorial Library (1963).
Victoria: University of Houston at Victoria Campus Library (1973).
Waco: Baylor University, Moody Memorial Library (1905).
Wichita Falls: Midwestern University, Moffett Library (1963).

UTAH

Cedar City: Southern Utah State College Library (1964).
Ephraim: Snow College, Lucy A. Phillips Library (1963).
Logan: Utah State University, Merrill Library and Learning Resources Center (1907)-REGIONAL.
Ogden: Weber State College, Stewart Library (1962).
Provo:
Brigham Young University, Harold B. Lee Library (1908).
Brigham Young University, Law Library (1972).
Salt Lake City:
University of Utah, Eccles Health Sciences Library (1970).
University of Utah, Law Library (1966).
University of Utah, Marriott Library (1893).
Utah State Library Commission, (unknown).
Utah State Supreme Court, Law Library (1975).

VERMONT

Burlington: University of Vermont, Bailey Library (1907).
Castleton: Castleton State College, Calvin Coolidge Library (1969).
Johnson: Johnson State College, John Dewey Library (1955).
Lyndonville: Lyndon State College, Samuel Reed Hall Library (1969).
Middlebury: Middlebury College, Egbert Starr Library (1884).
Montpelier: Vermont Department of Libraries (before 1895).
Northfield: Norwich University Library (1908).
South Royalton: Vermont School of Law Library (1978).

VIRGIN ISLANDS

St. Croix: Florence Williams Public Library (1974).
St. Thomas:
College of the Virgin Islands, Ralph M. Paiewonsky Library (1973).
Enid M. Baa Public Library (1968).

VIRGINIA

Blacksburg: Virginia Polytechnic Institute and State University, Carol M. Newman Library (1907).
Bridgewater: Bridgewater College, Alexander Mack Memorial Library (1902).
Charlottesville:
University of Virginia, Alderman Library (1910)-REGIONAL.

University of Virginia Law School, Arthur J. Morris Law Library (1964).
Chesapeake: Chesapeake Public Library (1970).
Danville: Danville Community College Library (1969).
Emory: Emory and Henry College, Kelly Library (1884).
Fairfax: George Mason University Library (1960).
Fredericksburg: Mary Washington College, E. Lee Trinkle Library (1940).
Hampden-Sydney: Hampden-Sydney College, Eggleston Library (1891).
Hampton: Hampton Institute, Huntington Memorial Library (1977).
Harrisonburg: James Madison University, Madison Memorial Library (1973).
Hollins College: Hollins College, Fishburn Library (1967).
Lexington:
Virginia Military Institute, Preston Library (1874).
Washington and Lee University, Cyrus Hall McCormick Library (1910).
Washington and Lee University, Wilbur C. Hall School of Law Library (1978).
Martinsville: Patrick Henry Community College Library (1971).
Norfolk:
Norfolk Public Library (1895).
Old Dominion University Library (1963).
U.S. Armed Forces Staff College Library (1963).
Petersburg: Virginia State College, Johnston Memorial Library (1907).
Quantico:
Federal Bureau of Investigation, Academy Library (1970).
U.S. Marine Corps Schools, James Carson Breckinridge Library (1967).
Reston: Department of the Interior, Geological Survey, National Center Library (1962).
Richmond:
University of Richmond, Boatwright Memorial Library (1900).
U.S. Court of Appeals, Fourth Circuit Library (1973).
Virginia Commonwealth University, James Branch Cabell Library (1971).
Virginia State Law Library (1973).
Virginia State Library (unknown).
Roanoke: Roanoke Public Library (1964).
Salem: Roanoke College Library (1886).
Williamsburg:
College of William and Mary, Marshall-Wythe Law Library (1978).
College of William and Mary, Swem Library (1936).
Wise: Clinch Valley College, John Cook Wyllie Library (1971).

WASHINGTON

Bellingham: Western Washington University, Mabel Zoe Wilson Library (1963).
Cheney: Eastern Washington University Library (1966).
Ellensberg: Central Washington University Library (1962).
Everett: Everett Public Library (1914).
Olympia:
Evergreen State College, Daniel J. Evans Library (1972).
Washington State Library (unknown)–REGIONAL.
Port Angeles: North Olympic Library System (1965).
Pullman: Washington State University Library (1907).
Seattle:
Seattle Public Library (1908).
University of Washington Libraries (1890).
University of Washington, Law Library (1965).
Spokane:
Gonzaga University, School of Law Library (1979).
Spokane Public Library (1910).
Tacoma:
Tacoma Public Library (1894).
University of Puget Sound, Collins Memorial Library (1938).
University of Puget Sound, School of Law Library (1978).
Vancouver: Fort Vancouver Regional Library (1962).
Walla Walla: Whitman College, Penrose Memorial Library (1890).

WEST VIRGINIA

Athens: Concord College Library (1924).
Bluefield: Bluefield State College Library (1972).
Charleston:
Kanawha County Public Library (1952).
West Virginia College of Graduate Studies Library (1977).
West Virginia Library Commission (unknown).
West Virginia Supreme Court Law Library (1977).
Elkins: Davis and Elkins College Library (1913).
Fairmont: Fairmont State College Library (1884).
Glenville: Glenville State College, Robert F. Kidd Library (1966).
Huntington: Marshall University, James E. Morrrow Library (1925).
Institute: West Virginia State College, Drain-Jordan Library (1907).
Morgantown: West Virginia University Library (1907)–REGIONAL.
Salem: Salem College Library (1921).
Shepherdstown: Shepherd College Library (1971).
Weirton: Mary H. Weir Public Library (1963).

WISCONSIN

Appleton: Lawrence University, Seeley G. Mudd Library (1869).
Beloit: Beloit College Libraries (1888).
Eau Claire: University of Wisconsin-Eau Claire, William D. McIntyre Library (1951).
Fond du Lac: Fond du Lac Public Library (1966).
Green Bay: University of Wisconsin-Green Bay Library (1968).
La Crosse:
La Crosse Public Library (1883).
University of Wisconsin-La Crosse, Murphy Library (1965).
Madison:
Madison Public Library (1965).
State Historical Society Library (1870)–REGIONAL, in cooperation with University of Wisconsin-Madison, Memorial Library.
University of Wisconsin-Madison, Memorial Library (1939).
Wisconsin State Law Library (unknown).
Milwaukee:
Alverno College Library (1971).
Milwaukee County Law Library (1934).
Milwaukee Public Library (1861)–REGIONAL.
Mount Mary College Library (1964).
University of Wisconsin-Milwaukee Library (1960).
Oshkosh: University of Wisconsin-Oshkosh, Forrest R. Polk Library (1956).
Platteville: University of Wisconsin-Platteville, Karrmann Library (1964).
Racine: Racine Public Library (1898).
River Falls: University of Wisconsin-River Falls, Chalmer Davee Library (1962).
Stevens Point: University of Wisconsin-Stevens Point, Learning Resources Center (1951).
Superior:
Superior Public Library (1908).
University of Wisconsin-Superior, Jim Dan Hill Library (1935).
Waukesha: Waukesha Public Library (1966).
Wausau: Marathon County Public Library (1971).

Whitewater: University of Wisconsin-Whitewater, Harold Andersen Library (1963).

WYOMING

Casper: Natrona County Public Library (1929).
Cheyenne:
Wyoming State Law Library (1977).
Wyoming State Library (unknown)-REGIONAL.
Laramie:
University of Wyoming, Coe Library (1907).
University of Wyoming, School of Law Library (1978).
Powell: Northwest Community College Library (1967).
Riverton: Central Wyoming College Library (1969).
Rock Springs: Western Wyoming Community College Library (1969).
Sheridan: Sheridan College, Kooi Library (1963).

APPENDIX B. DISTRICT OFFICES OF THE U.S. DEPARTMENT OF COMMERCE

ALABAMA

Birmingham—Gayle C. Shelton, Jr., Director, Suite 200-201, 908 South 20th Street, 35205, Area Code 205 Tel 254-1331, FTS 229-1331

ALASKA

Anchorage—Blaine D. Porter, Director, 701 C Street, P.O. Box 32, 99513, Area Code 907 Tel 271-5041, FTS Dial 8 399-0150, Ask for 271-5041

ARIZONA

Phoenix—Donald W. Fry, Director, Suite 2950 Valley Bank Center, 201 North Central Avenue 85073, Area Code 602 Tel 261-3285, FTS 261-3285

ARKANSAS

Little Rock—Robert E. Kistler, Director, Suite 635, Savers Federal Building, 320 W. Capitol Avenue, 72201, Area Code 501 Tel 378-5794, FTS 740-5794

CALIFORNIA

Los Angeles—Paul W. Leinenbach, Director, Room 800, 11777 San Vicente Boulevard 90049, Area Code 213 Tel 824-7591, FTS 799-7591

•**San Diego**—110 West C Street, 92101, Area Code 714 Tel 293-5395

San Francisco—Betty D. Neuhart Director, Federal Building, Box 36013, 450 Golden Gate Avenue 94102, Area Code 415 Tel 556-5860, FTS 556-5868

COLORADO

Denver—Donald L. Schilke, Director, Room 177, U.S. Customhouse, 721-19th Street, 80202, Area Code 303 Tel 837-3246, FTS 327-3246

CONNECTICUT

Hartford—Director (Vacant), Room 610-B, Federal Office Building, 450 Main Street 06103, Area Code 203 Tel 244-3530, FTS 244-3530

FLORIDA

Miami—Ivan A. Cosimi, Director, Room 821, City National Bank Building, 25 West Flagler Street 33130, Area Code 305 Tel 350-5267, FTS 350-5267

••**Clearwater**—128 North Osceola Avenue 33515, Area Code 813 Tel 461-0011

•**Jacksonville**—815 S. Maine Street, Suite 100, 32207, Area Code 904 Tel 791-2796, FTS 946-2796

•**Tallahassee**—Collins Bldg., Rm. G-20 32304, Area Code 904 Tel 488-6469, FTS 946-4320

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Savannah—James W. McIntire, Director, 222 U.S. Courthouse & P.O. Box 9746, 125-29 Bull Street, 31412, Area Code 912 Tel 944-4204, FTS 248-4204

HAWAII

Honolulu—H. Tucker Gratz, Director, 4106 Federal Building, P.O. Box 50026, 300 Ala Moana Boulevard 96850, Area Code 808 Tel 546-8694, FTS 8 808-546-8694

ILLINOIS

Chicago—Gerald M. Marks, Director, 1406 Mid Continental Plaza Building, 55 East Monroe Street 60603, Area Code 312 Tel 353-4450, FTS 353-4450

••**Commerce Business Daily** Room 1304, 433 West Van Buren Street 60607, Area Code 312 Tel 353-2950

INDIANA

Indianapolis—Mel R. Sherar, Director, 357 U.S. Courthouse & Federal Office Building, 46 East Ohio Street 46204. Area Code 317 Tel 269-6214, FTS 331-6214

IOWA

Des Moines—Jesse N. Durden, Director, 817 Federal Building, 210 Walnut Street 50309, Area Code 515 Tel 284-4222, FTS 862-4222

KENTUCKY

Louisville—Donald R. Henderson, Director, Room 636B, U.S. Post Office and Court House Building 40202, Area Code 502 Tel 582-5066, FTS 352-5066

LOUISIANA

New Orleans—Raymond E. Eveland, Director, 432 International Trade Mart, No. 2 Canal Street 70130, Area Code 504 Tel 589-6546, FTS 682-6546

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Boston—Francis J. O'Connor, Director 10th Floor, 441 Stuart Street 02116, Area Code 617 Tel 223-2312, FTS 223-2312

MICHIGAN

Detroit—Raymond R. Riesgo, Director, 445 Federal Building, 231 West Layfayette 48226, Area Code 313 Tel 226-3650, FTS 226-3650

••**Grand Rapids**—300 Monroe N.W., Rm. 409 49503 Area Code 616 Tel 456-2411/33 FTS 372-2411

MINNESOTA

Minneapolis—Glenn A. Matson, Director, 218 Federal Building, 110 South Fourth Street 55401, Area Code 612 Tel 725-2133, FTS 725-2133

MISSISSIPPI

Jackson—Mark E. Spinney, Director, City Center Plaza, Suite 550, 200 East Pascagoula 39201, Area Code 601 Tel 960-4388, FTS 490-4388

MISSOURI

St. Louis—Donald R. Loso, Director, 120 South Central Avenue 63105, Area Code 314 Tel 425-3302-4, FTS 279-3302

Kansas City—James D. Cook, Director, Room 1840, 601 East 12th Street 64106, Area Code 816 Tel 374-3142, FTS 758-3142

NEBRASKA

Omaha—George H. Payne, Director, Empire State Bldg., 1st Floor, 300 South 19th Street, 68102, Area Code 402 Tel 221-3664, FTS 864-3664

NEVADA

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127	SN 003-003-02195-4	$ 3.75			135	SN 003-003-02356-6	$ 4.50		
128	SN 003-003-02269-1	$ 4.00			136	SN 003-003-02363-9	$ 7.00		

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1113-2	SN 003-003-02235-7	$ 6.00			1138	SN 003-003-02317-5	$ 2.75		
1115	SN 003-003-02231-4	$ 3.25			1139	SN 003-003-02360-4	$ 4.50		
1118	SN 003-003-02191-1	$ 3.50			1140	SN 003-003-02306-0	$ 4.00		
1120	SN 003-003-02213-6	$ 2.25			1143	SN 003-003-02330-2	$ 2.50		
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Supplement 6: 1981

5. AUTHOR(S)

Linda Beavers, Editor

6. PERFORMING ORGANIZATION (If joint or other than NBS, see instructions)

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This document is divided into three main sections. The first, Titles and Abstracts, provides the report title, author(s), date of publication, selected key words, and an abstract of each NBS publication and each paper published in an outside source. The Author Index cites CBT authors and their publication number which is listed in this supplement. The Key Word Index is a subject index, listing word summaries of the building research topics for each publication and paper. By selecting a main word or subject, the user is able to locate reports of interest through these subject-related words.

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NOTE: The principal publication outlet for the foregoing data is the Journal of Physical and Chemical Reference Data (JPCRD) published quarterly for NBS by the American Chemical Society (ACS) and the American Institute of Physics (AIP). Subscriptions, reprints, and supplements available from ACS, 1155 Sixteenth St., NW, Washington, DC 20056.

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