# 1982 BUILDING TECHNOLOGY PUBLICATIONS

*U.S. Department of Commerce*
*National Bureau of Standards*
*Special Publication 457-7*

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# BUILDING TECHNOLOGY PUBLICATIONS

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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 1982. It is the seventh 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, 1982. 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 1982, appeared in several NBS publication series (Building Science Series, Technical Notes, 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
SP - Special Publication
J. Res. - Journal of Research
NBSIR - National Bureau of Standards Interagency Report
GCR - Grant/Contract Report

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 each 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 research in various areas. Interested readers will find other NBS publications listed in NBS Special Publication 305-14, *Publications of the National Bureau of Standards 1982*, from which parts of this report have been taken.

# OBTAINING PUBLICATIONS

Most current CBT publications (excluding *NBS Interagency Reports and Grant/Contract Reports*) are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Microfiche and paper copies of most CBT publications may be ordered through the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161. Two other sources are depository libraries (libraries designated to receive Government publications) and Department of Commerce District Offices. The current price list and availability of publications listed in this report are given in Appendix C.

The depository libraries listed in Appendix A receive selected publication series of the National Bureau of Standards for general reference use. While every Government publication cannot be sent to all depository libraries, certain designated Regional libraries are required to receive and retain one copy of all Government publications made available either in printed or microfiche form. To obtain information on which publications are available, please contact the depository library in your area.

Department of Commerce District Offices are maintained in the cities listed in Appendix B. Their purpose is to provide ready access at the local level to publications, statistical statements, and surveys. Each District Office serves as an official sales agency of the Superintendent of Documents, U.S. Government Printing Office. These offices make available for local purchase a wide range of Government publications. The reference library maintained by each District Office contains many Government and private publications, periodicals, directories, reports, and other reference materials.

# CONTENTS

# TITLES AND ABSTRACTS

# 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.

**BSS137.** Gujral, P. S.; Clark, R. J.; Burch, D. M. **An evaluation of thermal energy conservation schemes for an experimental masonry building.** *Natl. Bur. Stand. (U.S.) Bldg. Sci. Ser. 137;* 1982 July. 39 p SN003-003-02401-5.

Key words: building thermal mass; dynamic performance of buildings; energy conservation; heat transfer in buildings; night space cooling; night ventilation; passive solar heating.

A one-room masonry building with exterior polystyrene rigid board insulation was built within a large environmental chamber at the National Bureau of Standards. Various climatic conditions were simulated within the chamber, and the transient thermal response of the test building was monitored. Three schemes (night cooling using a ceiling-mounted valance cooling coil, natural ventilation night cooling, and passive solar heating) were investigated with regard to energy conservation. The test results indicated that these operating practices resulted in a considerable reduction in energy consumption for space heating and cooling.

The measured performance of the test building compared favorably with the corresponding performance obtained with an analytic model.

**BSS138.** Dobry, R.; Ladd, R. S.; Yokel, F. Y.; Chung, R. M.; Powell, D. **Prediction of pore water pressure buildup and liquefaction of sands during earthquakes by the cyclic strain method.** *Natl. Bur. Stand. (U.S.) Bldg. Sci. Ser. 138;* 1982 July. 168 p. SN003-003-02412-1.

Key words: cyclic strain; damping ratio; earthquake engineering; laboratory testing; liquefaction; particulate mechanics; particulate model; pore water pressure; sand; seismic loading; shear modulus; shear strain; site stability.

A cyclic strain approach for evaluating the buildup of excess pore water pressures and the potential for liquefaction of level sandy sites during earthquakes is proposed in this report. This strain approach is based on the premise that, for undrained loading of sand, there is a predictable correlation between cyclic shear strain and excess pore water pressure; also, that there is a threshold shear strain below which there is no sliding at the contacts between sand particles and no pore water pressure buildup can occur. As the result, a sand deposit will not develop excess pore pressures if the induced seismic shear strain is less than the threshold strain. Both theoretical evidence and experimental verification supporting the cyclic strain approach and the existence of the threshold, are presented in the report. Based on all these findings, a specific design method is proposed for predicting if excess pore pressures will develop at a specific site during a design earthquake.

**BSS139.** Swaffield, J. A. **Application of method of characteristics to model the transport of discrete solids in partially-filled pipe flow.** *Nat. Bur. Stand. (U.S.) Bldg. Sci. Ser. 139;* 1982 February. 116 p. Available from: NTIS; PB 82-237405.

Key words: computer based model; drainage; solid transport; unsteady flow.

The flow depth and velocity changes across a moving solid in partially-filled pipe flow are predicted by means of the application of the method of characteristics to solve the unsteady flow equations.

Simplified force models are presented which, when used in conjunction with empirical relationships linking leakage flow past the solid to upstream specific energy, are sufficient to provide the required moving solid boundary conditions that allow solid velocity prediction.

A wide range of simulated transport conditions are presented that confirm the applicability of this technique as a basis for the future evaluation of more complex body force models.

The predicted solid velocity during drain transport is shown to be compatible with laboratory observations of the influence of solid dimensions and position in inflow profile on transport characteristics.

**BSS140.** Fanney, A. H.; Thomas, W. C.; Scarbrough, C. A.; Terlizzi, C. P. **Analytical and experimental analysis of procedures for testing solar domestic hot water systems.** *Natl. Bur. Stand. (U.S.) Bldg. Sci. Ser. 140;* 1982 February. 158 p. SN003-003-02387-6.

Key words: ASHRAE Standard 95; collectors in parallel; electric strip heaters; environmental conditions; indoor testing; modeling; NBS; solar; solar domestic hot water system; stratification; test method.

A repeatable test method independent of outdoor environmental conditions and laboratory geographical location is required in order to provide a means by which solar domestic hot water systems may be rated and compared. Three experimental techniques which allow the net thermal output of an irradiated solar collector array to be reproduced indoors without the use of a solar simulator are investigated. These techniques include use of an electric heat source only, use of a nonirradiated collector array in series with an electric heat source, and the use of electric strip heaters which are attached to the back of nonirradiated absorber plates. Expressions are developed to compute the input power required for each experimental technique. Solar collectors connected in parallel and series combinations are considered.

All three test techniques were shown to reproduce the outdoor daily collector array thermal output within four percent. Two of the techniques allow the actions of the circulator controller for an outdoor irradiated system to be duplicated indoors. One technique applies to solar hot water systems which operate on the thermosyphon principle.

Experiments conducted to determine the effect of storage tank temperature stratification on system performance for a single-tank direct solar hot water system are described. Several return tube designs, which introduce the solar heated water into the storage tank, were fabricated and tested to determine the influence of thermal stratification on system performance. The best return tube design increased the performance of the single-tank direct system approximately ten percent compared to a conventional return tube design.

An analytical model for a single-tank direct hot water system is developed. The model is used to support parametric studies for the thermal performance characteristics which result from the use of each test method to duplicate the net thermal output of an irradiated array. The model is also used to assess thermal performance differences which occur due to indoor versus outdoor environmental conditions.

**BSS141.** Collins, B. L. **The development and evaluation of effective symbol signs.** *Natl. Bur. Stand. (U.S.) Bldg. Sci. Ser. 141;* 1982 May. 96 p. SN003-003-02398-1.

Key words: communication; design issues; hazard; pictograms;

pictorial; safety; signs; standards; symbols; visual alerting; warning.

Graphic symbols have recently been widely adopted for sign systems in the United States. Beginning with traffic sign systems, symbols have become widely used for applications ranging from products to buildings. In this report a brief history of the development of symbols is given, followed by a review of research on experimental evaluation of symbols. Some of the general advantages and limitations of symbols are discussed, along with graphic considerations essential in the development of effective symbols. Research on symbols for five areas of application—highway, automotive/machinery, public information, product hazard, and safety—is then discussed.

Finally, issues in the research and development of more effective symbols are reviewed. These include the need for good graphic design, characteristics of the intended user group, use of shape and color to encode information, and general visibility considerations.

BSS142. Yokel, F. Y.; Chung, R. M.; Rankin, F. A.; Yancey, C. W. C. **Load-displacement characteristics of shallow soil anchors.** *Natl. Bur. Stand. (U.S.) Bldg. Sci. Ser. 142;* 1982 May. 163 p. SN003-003-02394-9.

Key words: anchors; cyclic loading; field testing; flood forces; foundations; load capacity; mobile homes; soil anchors; soil mechanics; stiffness; wind forces.

Tests on shallow soil anchors, commonly used by the mobile home industry, including 6-in single helix and 4-in double helix anchors as well as three types of swivel anchors, were conducted on three sites: a silty site, a sandy site, and a clay site. Test variables included direction of anchor installation; direction of loading; anchor depth; size of anchor plate; and cyclic load effects. The effect of these test variables on load-displacement characteristics, measured at the anchor head, is investigated. It is concluded that on most sites the anchor types tested, when installed in accordance with present industry practice for mobile home tiedown systems, did not deliver the anchor performance required in present standards. It is recommended that minimum load capacity requirements for anchors be waived; that all anchors be preloaded to 1.25 times the design load; and that one anchor per mobile home, or three anchors per site if soil conditions are uniform, be preloaded to 1.5 times the design load.

BSS143. Marshall, R. D.; Pfrang, E. O.; Leyendecker, E. V.; Woodward, K. A.; Reed, R. P.; Kasen, M. B.; Shives, T. R. **Investigation of the Kansas City Hyatt Regency walkways collapse.** *Natl. Bur. Stand. (U.S.) Bldg. Sci. Ser. 143;* 1982 May. 360 p. SN003-003-02397-3.

Key words: building; collapse; connection; construction; failure; steel; walkway.

An investigation into the collapse of two suspended walkways within the atrium area of the Hyatt Regency Hotel in Kansas City, Mo., is presented in this report. The investigation included on-site inspections, laboratory tests and analytical studies.

Three suspended walkways spanned the atrium at the second, third, and fourth floor levels. The second floor walkway was suspended from the fourth floor walkway which was directly above it. In turn, this fourth floor walkway was suspended from the atrium roof framing by a set of six hanger rods. The third floor walkway was offset from the other two and was independently suspended from the roof framing by another set of hanger rods. In the collapse, the second and fourth floor walkways fell to the atrium floor with the fourth floor walkway coming to rest on top of the lower walkway.

Based on the results of this investigation, it is concluded that the most probable cause of failure was insufficient load capacity of the box beam-hanger rod connections. Observed distortions of structural components strongly suggest that the failure of the walkway system initiated in the box beam-hanger rod connection on the east end of the fourth floor walkway's middle box beam.

Two factors contributed to the collapse: inadequacy of the original design for the box beam-hanger rod connection which was identical for all three walkways, and a change in hanger rod arrangement during construction that essentially doubled the load on the box beam-hanger rod connections at the fourth floor walkway. As originally approved for construction, the contract drawings called for a set of continuous hanger rods which would attach to the roof framing and pass through the fourth floor box beams and on through the second floor box beams. As actually constructed, two sets of hanger rods were used, one set extending from the fourth floor box beams to the roof framing and another set from the second floor box beams to the fourth floor box beams.

Based on measured weights of damaged walkway spans and on a videotape showing occupancy of the second floor walkway just before the collapse, it is concluded that the maximum load on a fourth floor box beam-hanger rod connection at the time of collapse was only 31 percent of the ultimate capacity expected of a connection designed under the Kansas City Building Code. It is also concluded that had the original hanger rod arrangement not been changed, the connection capacity would have been approximately 60 percent of that expected under the Kansas City Building Code. With this change in hanger rod arrangement, the ultimate capacity of the walkways was so significantly reduced that, from the day of construction, they had only minimal capacity to resist their own weight and had virtually no capacity to resist additional loads imposed by people.

BSS144. Crenshaw, R.; Clark, R. E. **Optimal weatherization of low-income housing in the U.S.: A research demonstration project.** *Natl. Bur. Stand. (U.S.) Bldg. Sci. Ser. 144;* 1982 September. 166 p. SN003-003-02437-6.

Key words: Community Action Agencies; Community Services Administration; costs of residential weatherization; energy conservation; field measurement of building energy consumption; optimal weatherization; residential energy consumption; weatherization.

This report describes and presents the results of the Community Service Administration's (CSA's) Optimal Weatherization Demonstration Research Project carried out by the National Bureau of Standards (NBS). The CSA/NBS demonstration installed both architectural (building shell) and mechanical systems building weatherization options, and achieved, when both types of options were used, an average reduction in space heating fuel consumption of 41 percent, at an average weatherization cost of $1862 per house.

The report explains the rationale used for selecting a sample of more than 200 houses at 12 sites across the United States, and for selecting optimal levels of weatherization for each of the houses. It presents measured energy consumption and detailed descriptive data on the houses before and after weatherization, the percentage savings achieved, and shows the costs of infiltration, conduction, furnace and water heater retrofits. Finally, it reports what options actually were installed in each house, and describes how data on the performance of those options were gathered and analyzed.

BSS145. Lew, H. S.; Carino, N. J.; Fattal, S. G.; Batts, M. E. **Investigation of construction failure of Harbour Cay condominium in Cocoa Beach, Florida.** *Natl. Bur. Stand. (U.S.) Bldg. Sci. Ser. 145;* 1982 August. 135 p. SN003-003-02405-8.

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

The investigation of the collapse of a five-story reinforced concrete flatplate 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 stage and the other in the construction stage. 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 analysis of the structure indicated that 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 concrete prior to the collapse.

**BSS147.** Center for Building Technology. **Performance criteria for solar heating and cooling systems in residential buildings.** *Natl. Bur. Stand. (U.S.) Bldg. Sci. Ser. 147;* 1982 September. 236 p. SN003-003-02418-0.

Key words: building; cooling; heating; hot water; performance criteria; solar energy; standards.

This performance criteria, developed for the Department of Housing and Urban Development, is a baseline document for criteria and standards for the design, development, technical evaluation, and procurement of solar heating and cooling systems for residential buildings in accordance with the requirements of Section 8 of Public Law 93-409, the "Solar Heating and Cooling Demonstration Act of 1974." The document is intended to establish minimum levels of performance with regard to health and safety and the various aspects of technical performance. The criteria for health and safety put primary emphasis on compliance with existing codes and standards. The criteria on thermal and mechanical performance, durability/reliability and operation/servicing present performance requirements considered to be representative of acceptable levels. By the use of performance language in the document, it is believed that sufficient latitude has been provided to allow the innovation and flexibility that is essential for the stimulation of a viable solar industry at this time and in the future.

**BSS148.** Lew, H. S.; Fattal, S. G.; Shaver, J. R.; Reinhold, T. A.; Hunt, B. J. **Investigation of construction failure of reinforced concrete cooling tower at Willow Island, WV.** *Natl. Bur. Stand. (U.S.) Bldg. Sci. Ser. 148;* 1982 September. 156 p. SN003-003-02436-8.

Key words: collapse; concrete; concrete strength; construction; cooling tower; failure; hyperbolic shell; shell.

The collapse of the natural-draft hyperbolic concrete cooling tower unit no. 2 at the Pleasants Power Station at Willow Island, West Virginia, was investigated by the National Bureau of Standards. The investigation included on-site inspections, laboratory tests of construction assembly components and concrete specimens, and analytical studies.

Based on the results of these field, laboratory, and analytical investigations, it was concluded that the most probable cause of the collapse was due to the imposition of construction loads on the shell before the concrete of lift 28 had gained adequate strength to support these loads. The analysis of the shell indicated that the collapse initiated at the part of the shell in lift 28 where cathead no. 4 was located. It further showed that calculated stress resultants at several points in that part equaled or exceeded the strength of the shell in compression, bending, and shear. The failure of these points in that part of the shell would have propagated to cause the collapse of the entire lift 28.

**BSS149.** Salomone, L. A.; Kovacs, W. D.; Wechsler, H. **Thermal behavior of fine-grained soils.** *Natl. Bur. Stand. (U.S.) Bldg. Sci. Ser. 149;* 1982 November. 102 p. SN003-003-02463-5.

Key words: Atterberg Limit tests; compaction; compaction tests; heat flow; laboratory tests; soil moisture; soil tests; tests; thermal conductivity; thermal resistivity.

Laboratory thermal probe tests performed on an AASHTO standard reference material (a silty clay) showed that thermal resistivity (°C-cm/watt) varies with soil moisture content and dry density. The tests were performed to correlate soil thermal behavior with the limit states of fine-grained soils. Over 80 thermal resistivity measurements were made on specimens compacted to various densities and moisture contents.

Results are presented which indicate that the optimum moisture content of soils and the Atterberg Limits can be correlated with the thermal behavior of fine-grained soils. It was found that the minimum thermal resistivity (i.e., the critical moisture content) occurred at the optimum moisture content when the soils were compacted using various compactive efforts. The critical moisture content defines the knee of the thermal resistivity versus moisture content curve. When the soils were compacted using a compactive effort of $1.42 \times 10^5$ J/m$^3$ (2970 ft-lbs per cubic foot), the minimum thermal resistivity occurred at the plastic limit of the AASHTO standard reference material. Also, indices are defined which allow comparison of the thermal behavior of fine-grained soils.

# 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.

**TN1150.** Pommersheim, J. M.; Campbell, P. G.; McKnight, M. E. **Mathematical models for the corrosion protective performance of organic coatings.** *Natl. Bur. Stand. (U.S.) Tech. Note 1150;* 1982 September. 99 p. SN003-003-02417-1.

Key words: absorption; adhesion; adsorption; conceptual models; corrosion; mathematical models; organic coating; osmosis; osmotic pressure; oxygen; permeability; pigment; protective performance; substrate; vehicle; water.

Mathematical models were developed for conceptual models describing the principal phenomena that occur in the corrosion performance of polymeric coatings. These include models for water and oxygen permeability through organic coatings, models for the growth of blisters beneath coatings, and preliminary models for the polarization occurring at the electrode surfaces. Results predicted by the models are discussed in terms of the improvement of the protective function of the membrane.

**TN1156.** Clark, R. E. **The CSA weatherization demonstration data base: Contents and descriptions.** *Nat. Bur. Stand. (U.S.) Tech. Note 1156;* 1982 February. 159 p. SN003-003-02385-0.

Key words: Community Services Administration Weatherzation Demonstration; costs of weatherization; energy conservation; energy consumption data; energy related data; field measurement of building energy use; Optimal Weatherization Demonstration; residential energy consumption; space heating consumption; weatherization.

The Community Services Administration (CSA) National Optimal Weatherization Demonstration was conducted over a 3 1/2 year period (1977-1981) by the National Bureau of Standards and Community Action agencies in 12 areas around the Nation, principally to determine what reductions in residence space heating energy consumption could be achieved by extensive, economically cost-effective weatherization of dwellings. Because the project was

funded by the CSA, it was conducted using houses occupied by low-income households. In addition to recording overall energy consumption (for the 1975–1980 period), the demonstration collected considerable additional energy-related measurements from approximately 240 houses (including some 40 unweatherized control houses) at the 12 sites. These measurements probably constitute the most extensive and comprehensive data base on real energy usage of real houses extant. The report describes the various measurements that were obtained and how they were obtained. It contains house-by-house inventories of the data actually present in the data base and, as an access aid for further study of the data, it describes the media in which the data exist.

**TN1167.** Calabrese, J. T.; Kaetzel, L. J.; Glass, R. A.; Smith, G. R. **A computer data base system for indexing research papers.** *Natl. Bur. Stand. (U.S.) Tech. Note 1167;* 1982 October. 102 p. SN003-003-02432-5.

Key words: computer indexing; data base; directory look-up; information retrieval; interactive processing; random access.

This report represents a significant revision to NBS Technical Note 1123 published in 1980. In that report, the Kaetzel, Glass, Smith (KGS) data base system permitted users to index, edit, classify, and retrieve scientific research paper citations. During the past 15 months, the system was modified and enhanced. All programs are written in standard FORTRAN VII Level I programming language providing transportability among computer systems. Retrieval time has been greatly reduced by changing from a sequential access method to an indexed, directory look-up file structure which allows faster and more efficient random access. The file structure is machine independent. Because of the responsiveness of the extract mode, the one-key retrieval is unnecessary and has been deleted from the revised system. The keyword mode has been replaced by the information mode which provides statistics on authors and keywords. A file maintenance mode has been added to ensure data base integrity. The KGS system has been separated from the larger Publications Data Base and the select data base mode has been removed. Software has been tailored to meet KGS users' needs. Overall, the revised system is faster and uses resources more efficiently than the original data base.

**TN1170.** Clark, E. J.; Roberts, W. E. **Weathering performance of cover materials for flat plate solar collectors.** *Natl. Bur. Stand. (U.S.) Tech. Note 1170;* 1982 November. 80 p. SN003-003-02454-6.

Key words: artificial weathering; cover plate materials; durability; natural weathering; solar collectors; solar energy; solar energy transmittance; tensile properties; weathering of cover plates.

Weathering studies were performed to obtain data on the performance and durability of cover plate materials for flat plate solar collectors used in solar heating and cooling systems. Ten materials were evaluated to assess their durability after natural weathering and artificial weathering with a xenon arc light. The materials were weathered for four years on small minicollectors in Arizona, Florida, and Maryland after which the solar energy transmittance and the effect of dirt on the transmittance were measured. The tensile properties of selected film materials were also assessed after weathering. The effects of the natural weathering are compared: (1) for materials exposed as inner and outer cover plates for each weathering site; (2) for the three weathering sites; and (3) with materials artifically weathered with a xenon arc light.

# 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.

**SP446-6.** Raufaste, N.; Olmert, M. **Building technology project summaries 1981–1982.** *Natl. Bur. Stand. (U.S.) Spec. Publ. 446-6;* 1982 September. 72 p. Available from: NTIS; PB 83-118646.

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. The Center's activities support building technology programs of the Federal, State and local governments; assist design professions, building officials and the research community by providing design criteria that improve buildings; and assist manufacturers of building products by developing criteria for evaluating innovative building materials. This report summarizes the Center's projects for calendar years 1981–1982. It enables individuals to get a clear impression of CBT research activities.

**SP457-6.** Beavers, L., ed. **Building technology publications 1981—Supplement 6.** *Natl. Bur. Stand. (U.S.) Spec. Publ. 457-6;* 1982 June. 94 p. SN003-003-02439-2.

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

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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.

**SP624.** Dynamac Corporation. **Proceedings of the National Water Conservation Conference on Publicly Supplied Potable Water.** 1981 April 14-15; Denver, CO. *Natl. Bur. Stand. (U.S.) Spec. Publ. 624;* 1982 June. 467 p. Available from: NTIS; PB 82-234501.

Key words: municipal water systems; potable water reduction; water conservation.

This "Proceedings" is a complete compilation of the papers presented April 14 and 15, 1981, at the National Water Conservation Conference—Publicly Supplied Potable Water in Denver, CO. The

Conference was primarily directed toward elected and administrative officials of local governments, the individuals who are responsible in some part for the quantity and quality of water available to their communities.

Techniques for, and analysis of, potable water conservation and wastewater flow reduction were presented. The topics addressed included: Water-Saving Technology: Plumbing fixtures, testing and performance of low-flow devices, leak detection and repair, potential problems in wastewater flow reduction, and landscaping with native vegetation. Public Education and Motivation. Economics: Water pricing systems, analysis of cost/benefits, and development and management of data. Planning: State and local urban planning efforts for conservation, and Federal programs and incentives. Case Studies: From California, Washington, Utah, Arizona, North Carolina, Maryland, New Jersey, and Massachusetts. *These proceedings include the following papers (indented):*

**SP624;** 1982 June. 17-26. Walker, W. R. **Water law: Impact on conservation.**

Key words: conservation; riparian doctrine; water law.

Laws with respect to water are unusual because they may vary depending on the form in which water is found. It is further complicated because the states do not have uniform laws for water in its various forms. Water with bed and bank in the western United States must conform to the prior appropriation doctrine which places emphasis on the protection of private property rights rather than maximum utilization. Water in this same form in the East is governed by the riparian doctrine which defines the water rights according to the place of use. Water under the ground may follow the English, American, or reasonable use rule. Diffused water which flows over the surface of the ground must be captured to establish a right. All of these laws evolved generally for historical reasons and have been modified slightly by statutes but not uniformly. None were designed to reduce consumption, promote efficiency or facilitate change to a higher beneficial use. The development of constitutionally protected water rights has made change more difficult. Yet these laws and the institutional structures which have evolved to implement them must be modified to promote greater use of a finite resource.

**SP624;** 1982 June. 27-36. Nelson, J. O. **Motivating the public to save water in the absence of a crisis.**

Key words: consumer education; drought-tolerant plant; water conservation.

Managing municipal water demands on a regular basis can be an important tool in helping to balance the supply-demand equation. Various elements or techniques can be considered by the utility, i.e., consumer education, pricing formulas, devices suitable for retrofitting existing homes, devices suitable for new development, irrigation equipment, drought-tolerant plant materials, and codes and regulations. But how do you successfully implement these elements and induce consumers to save water when there is no spectre of a water shortage to help congeal public action? In this paper the author shares his experiences in implementing water conservation in the North Marin County Water District and provides some tips and advice that have evolved from this experience. The thrust is a "volunteerism" type approach that first seeks a commitment from the consumer, followed by education and supply of materials, and lastly, follow-through surveys to determine the effective penetration of the idea or technique. Much of the advice developed by the author parallels empirically derived criteria employed by successful advertising agencies.

**SP624;** 1982 June. 37-45. Preston, D. B. **Providing section services in technical information and training.**

Key words: American Water Works Association; technical information programs; technical information retrieval.

The American Water Works Association's (AWWA's) training and technical information programs have been undergoing a major evolutionary change over the past several years. The planning, development, and implementation of various programs administered by the education department have been a time-consuming process; currently, however, established programs are online and new directions are being examined to expand and improve member services.

What have been the primary causes that have brought about the dramatic changes in the Association's education services? Most visible has been the increase in staff from three to nine members in the past 5 years. The expansion of professional staff has been a building process of selecting persons with abilities in specialized areas of technical information retrieval, program coordination, and training materials development, who function as a team. The turning point, however, can be traced to two factors that have resulted in substantially changing the Association's posture and providing the impetus to move in new directions.

**SP624;** 1982 June. 47-51. Wilborn, D. P. **Water-saving plumbing: A flow control & maintenance program to reduce and control water use in multi-housing properties.**

Key words: control water flow; flow control devices; multi-housing properties; plumbing fixtures; water consumption; water-saving plumbing.

Evaluation of water consumption at multi-housing properties often reveals excessive and costly water use. The challenge to reduce and control water flow is being successfully met by a program designed to modify plumbing fixtures and provide management of water consumption.

**SP624;** 1982 June. 53-59. Schmidt, N. M. **Landscaping alternatives and irrigation conservation.**

Key words: faucet aerators; irrigation conservation; landscaping alternatives; water conservation; water-conserving devices.

I would like to make a few general comments concerning the subject of water conservation and what we in the home building industry are doing about that important subject. First, for the last 2 years the home building industry has been the recipient of a voluntary effort on behalf of the plumbing industry to provide water-conserving devices as standard equipment. New homes in Colorado have been receiving low-volume, 3-1/2-gallon toilets; low-volume showerheads; and faucet aerators. This is a dramatic case where voluntarism through private enterprise has moved at a faster pace than any government codes. Second, the trend toward smaller, more dense housing, which has primarily been motivated by issues of affordability, certainly has been a positive factor relative to water conservation. Outside irrigation demands are reduced by this trend toward more density. Third, I would hope that this audience would find the most recent National Association of Home Builders Consumer Survey very interesting. The historic main reasons for people buying new homes have been the need for moving to a larger home and moving to a nicer neighborhood. Energy has now become the number one subject of concern. Although the current main concern of energy is heating, the subject of water conservation also is included in the broad concern for energy-conserving homes.

**SP624;** 1982 June. 61-66. Lyon, J. S. **Water conservation: The leaks in implementation.**

Key words: conservation laws; Environmental Policy Institute; water conservation.

**SP624;** 1982 June. 69-80. Yeaman, B.; Wesely, E. F., Jr. **Developing and testing a water conservation handbook.**

Key words: Potomac River and Trails Council; Project Water Watch; wastewater treatment systems; water conservation.

How do we "sell" water conservation?

The advertising community would suggest that we begin by educating the residential consumer. "Easy Ways to Save Water, Money, and Energy at Home," a 32-page booklet produced by the Potomac River and Trails Council, was designed to do this.

What follows is the distillation of experience gained by the Environmental Protection Agency (EPA), which commissioned the booklet, and the Potomac River and Trails Council (PRTC), which designed and printed it.

We also describe "Project Water Watch," a program undertaken by PRTC in Frederick, Maryland, a small but developing city of 30,000 where there is no perceived water supply problem. With a small EPA grant, PRTC has been testing the attitudes of local residents about water conservation, and about the booklet "Easy Ways to Save Water, Money, and Energy at Home."

**SP624;** 1982 June. 81-90. Postel, S. L. **Flow reduction: Methods, analysis procedures, examples.**

Key words: flow reduction; wastewater treatment.

Increasing numbers of communities across the nation are realizing the benefits of flow reduction in managing their wastewater treatment facilities. Among these benefits are savings in wastewater treatment, water supply and energy costs, as well as the ability to meet a greater portion of future needs with existing treatment capacity. *Flow Reduction: Methods, Analysis Procedures, Examples* (1) was prepared for the Environmental Protection Agency (EPA) to assist communities in developing cost-effective flow reduction programs. The manual's flexible, yet structured step-by-step procedure is a useful guide to developing program alternatives, analyzing program benefits and costs from a community viewpoint, providing for adequate public participation, and selecting a recommended program based on the analysis results. The manual also provides detailed information on flow reduction measures and specific devices, including their associated costs and water and energy savings, as well as examples of how to calculate a program's net monetary benefits. Two additional volumes will supplement Parts I and II of this manual. Part III will demonstrate the manual's procedure using two real-world communities; Part IV will provide additional guidance and material for developing flow reduction public information programs.

**SP624;** 1982 June. 91-102. Fisher, D. L.; Yost, J. A. **State water conservation planning guide.**

Key words: U.S. Water Resources Council; water conservation; water resource management.

The U.S. Water Resources Council, under the authority of Title III of the Water Resources Planning Act of 1965, provides grants to States for the development of comprehensive water and related land resources plans. Through the water policy initiatives of President Carter in 1978, agencies were directed to emphasize the integration of water conservation in the implementation of water resource management programs. Acting upon these initiatives and the directives of the President, the Water Resources Council emphasized the integration of water conservation in State programs.

To assist States in this endeavor, the Council developed the State Water Conservation Planning Guide. The planning guide is to be used primarily by State water planners in establishing and implementing a water conservation program. The guide details many of the necessary actions to implement an effective water conservation program. A prime objective of this guide is to bridge the gap that exists in many States between State and local water planning and implementation efforts. It is imperative that the participation and support of local utilities, municipalities, and other water purveyors be solicited during plan development and extended into implementation. The philosophy and objective of the planning guide, the proposed implementation guide, and the Water Resources Council grant program were always to extend Federal assistance, both technical and financial, down to the States, and through the States to local water purveyors. To accomplish more efficient water use, Federal efforts must be carried down to the local level.

**SP624;** 1982 June. 103-111. Sanders, W.; Thurow, C. **The role of land use planning in water conservation.**

Key words: land use planning; residential development; water conservation.

Land use planning and the regulatory controls that grow out of this process influence demand for water. Land development policies are formulated in the planning process and implemented through land use regulations. These regulations, especially zoning and subdivision controls, influence how much water a municipality will need by regulating the types of buildings that are built, their location, and the way open space is used around them. This paper examines how this influence can be used to conserve water. Water conservation elements in comprehensive plans are considered along with patterns of development that conserve water. Land use regulations that can serve to implement water conserving residential development are also examined.

Land use planning can be important to water conservation. It can help conserve supplies or reduce demand. Traditionally, land use planners have not played a direct role in water supply planning, but for some time they have helped communities manage and protect watersheds or aquifer recharge zones that are threatened by urban growth. In recent years, a growing number of local planning agencies have recognized the potential for land use planning to reduce the need for urban water. Some communities are now including water conservation elements in their comprehensive plans, which identify both opportunities for water conservation and implementing strategies. A few communities have also built water conserving principles into their zoning and subdivision regulations.

**SP624;** 1982 June. 113-119. Rondon, J. **Aurora, Colorado: Rational landscape alternatives.**

Key words: water conservation program; water rights.

**SP624;** 1982 June. 123-133. Koyasako, J. S. **Water conservation and wastewater flow reduction—Is it worth it?.**

Key words: wastewater flow reduction; water conservation.

This question was the subject of a recent research study largely funded by the Environmental Protection Agency (EPA). Two study reports were prepared: a detailed report published by EPA and a summary report published by the California Department of Water Resources. This study of indoor water conservation and resulting wastewater flow reduction arrived at one main conclusion: There are overwhelming benefits to be derived from community water conservation programs and they should be vigorously promoted.

**SP624;** 1982 June. 147-150. Knox, P. C. **Planning for the future.**

Key words: source of supply; water conservation; water use habit changes.

There is a long-standing base of environmental consciousness among the people of the Pacific Northwest. The conservation ethic is an important part of policies and actions affecting the region's resources. In 1975 a number of prestigious policy-making bodies and organizations strongly recommended water conservation as an alternative to development of new resources. The low rainfall of 1976–77 was the incentive to the Seattle Water Department to consider the conservation alternative. The Department examined the feasibility of the subject during the three ensuing normal years and, in 1980, the City adopted a Conservation Program. Without an impending disaster, the Program could assume a course based upon human value and rationality associated with future sources of supply. A

cost/benefit analysis was conducted during the initial study for the Program based on an eight percent reduction in total demand to be reached over a ten-year period. The findings supported the adoption of the Program. The need to construct another source of supply will be delayed by six to seven years if the Program goal is reached. At the core of the Program are six voluntary cooperation projects and three public use management projects. Water customers were targeted and specific water use habit changes were identified to accomplish demand reductions through the projects. Program evaluation methods are being closely monitored by the City Council, which expects timely accomplishment of the projected reductions. Currently, the Office is involved in assessing evaluation in the light of staffing, methods and computer capabilities.

**SP624;** 1982 June. 151-154. Gillum, D. M. **Water conservation in Arizona: Past, present, and future.**

Key words: faucet aerators; flow reduction; groundwater law; public awareness; toilet dams; wastewater flow reduction; water conservation.

In the desert regions of Arizona and much of the Southwest, water is an extremely valuable commodity and should have the highest of priorities. Water conservation and good quality water are the key to our future and the future of our Nation. Arizona is currently involved in three water conservation programs. They are: 1) Beat the Peak and Slow the Flow, 2) Flow Reduction, and 3) A New Groundwater Law.

**SP624;** 1982 June. 155-156. Linsky, H. S. **Water conservation as a long-range supply option for Massachusetts: Dispelling the myths and facing reality.**

Key words: depletion of supply; myth of abundant water; quality degradation; water conservation.

The Metropolitan District Commission (MDC), serving Metropolitan Boston, is considering conservation as a long-term water supply option. The present MDC supply system has enormous storage capacity, however, and the impression of abundant water supply creates a situation quite different from the public perception of imminent shortages which characterize the national experience with water conservation.

A conceptual framework must be developed for converting national experience to realistic expectations for a long-range program in an area suffering from a myth of abundance but facing a gradual depletion of supply.

In order to include water conservation in long-range water supply plans we must scale down our expectations for potential demand reductions and be more realistic in our assessment of the costs and benefits of various programs.

**SP624;** 1982 June. 169-171. Frank, A. **Water conservation in rental apartment complexes by means of controlled installation of watersaving devices.**

Key words: controlled installation; leak detection; preventive maintenance; rental apartment complexes; waste flow; water conservation; watersaving devices.

Howard County, Maryland, in common with many other local jurisdictions, is experiencing rapid growth of its population and housing stock. As a result, it is expected that demand for water and sewer service will continue to increase, and that expansion of service into new areas will be necessary. In order to satisfy these needs, major new investment will be required. A primary strategy designed to offset the impact of this trend is reduction of per capita water use and waste flow.

The program which has been developed to implement the strategy will initially focus the County's efforts (to reduce water use and waste flow) on rental apartment complexes. It will be accomplished by employing a relatively unique concept: co-funded, controlled installation of watersaving devices concurrent with leak detection, repair, and preventive maintenance.

Howard County proposes that the development of a practical conservation program, based on controlled use of resources and corrective maintenance, will result in significant reductions of water (and energy) costs relative to investment, will enhance the state-of-the-art, and will provide a valuable case study for use by other jurisdictions.

**SP624;** 1982 June. 173-177. Barnett, J. A. **Enhanced water education versus status quo et al.**

Key words: water education; water education materials; water resource issues.

Water resource authorities, appointed by the governors of the twelve western states, determined six years ago that there was a significant need for better water education. These officials, members of the Western States Water Council, felt it was important for the public to be well informed on water resource issues as the nation moves ahead and faces many difficult water resource decisions. They determined that the Western States Water Council was not the appropriate vehicle for the preparation of these water education programs, and that the need for water education was not limited to the western United States. The Council instructed that a non-profit water education corporation be formed to pursue these most worthwhile educational efforts.

Water & Man, Inc. is the new non-profit corporation fostered by the Council, and has been growing from a very humble beginning six years ago, through various stages of support, solicitation, fundraising, and the creation of water education materials. The Trustees of Water & Man have determined that their first effort would be to prepare and disseminate quality water education materials to be used in the public schools of the nation in grades K-12. Initial materials have been prepared and they are currently being disseminated to participating states.

**SP624;** 1982 June. 179-190. Baumann, D. D. **Information and consumer adoption of water conservation measures.**

Key words: public education programs; urban water resource planning; water conservation.

Educational campaigns concerning a specific issue are likely to fail unless they are based upon specific information about the recipients. There is some experience that some consumers respond to pleas for reducing water use during periods of shortage. However, during nondrought periods, more specific information is needed in order to design an effective water conservation program: it simply is not sufficient to assume that knowledge of water conservation measures will result in adoption.

**SP624;** 1982 June. 193-196. Pabon, Sims, Smith, and Associates, Inc. **Residential water conservation handbook.**

Key words: appliances; conservation programs; residential water conservation; water-saving plumbing devices.

This practical guide to residential water conservation entails the review and evaluation of water-saving plumbing devices, appliances, and techniques for their technical and economic feasibility, as well as their public acceptance and regional applicability. The resulting consumer handbook aimed at the homeowner was produced to help consumers conserve water. The handbook was market tested for content, theme, readability, language and style. A national information dissemination plan was researched to ensure widespread distribution of the handbook to targeted audiences.

**SP624;** 1982 June. 197-206. Crews, J. E.; Schilling, K. E. **A procedures manual for evaluating water conservation planning.**

Key words: groundwater resources; water conservation planning; water resource development; water resources.

In the past few years, the role of water conservation in the management and planning of water resources has become increasingly important. A number of factors account for this emphasis: (1) new reservoir sites have become increasingly scarce; (2) concern for environmental quality has grown; (3) groundwater resources are increasingly inadequate to meet the demands of urban areas; (4) political, economic, and institutional problems of interbasin transfers have proliferated, making it nearly impossible to plan for transfer of water from one basin to another; (5) the costs of water resource development have risen enormously in the last decade as a result of the increase in the price of energy, the increase in the cost of money, and the rise in water quality standards as manifested in the passage of Federal legislation such as the Federal Water Pollution Control Act Amendments (1972), the Safe Drinking Water Act of 1974, and the Clean Water Act of 1977; and (6) the demand for urban water has continued to increase. In combination, these factors have created a situation which directs attention to the possibilities of water conservation.

The Corps of Engineers recognized these trends and began policy studies and research early in 1978 to define and integrate water conservation into its Civil Works program. This paper presents one of the major outputs of this research effort and discusses how the Corps views water conservation.

**SP624;** 1982 June. 207-209. Craft, G. L. **AWWA water conservation handbook.**

Key words: American Water Works Association (AWWA); conservation policy; water conservation.

**SP624;** 1982 June. 211-223. Water Supply/Conservation Program Staff. **Before the Well Runs Dry: A handbook for designing a local water conservation plan.**

Key words: water conservation plan; water supply planners.

In February 1979, the New England River Basins Commission (NERBC) received funds from the U.S. Geological Survey (USGS), Resources and Land Investigations Program, to research and develop a planning procedure for water conservation. The project included an extensive literature search, development of local case studies, interviews with water supply engineers and policy makers, and an evaluation of the effectiveness of alternative water conservation measures. From the information it gathered and analyzed, NERBC developed a seven-step procedure for designing a local conservation plan. The sources for the procedure and the procedure itself are presented in a two-volume technical report, *Before the Well Runs Dry.*

In 1980, NERBC received additional funds from USGS's Water Resources Division to prepare a handbook for the practical application of the information contained in the technical report. The handbook is designed to provide a concise, clear-cut procedure for local water supply planners to follow in designing a conservation plan. The procedure outlined in the handbook has been reviewed by water supply engineers, administrators, superintendents, and planners throughout New England. It is flexible, can be used by any type of water utility, and can meet a variety of goals. This paper summarizes the information presented in the handbook.

**SP624;** 1982 June. 227-238. Weber, S. F.; Lippiatt, B. C.; Hillstrom, A. P. **Cost-effective residential water conservation decisions.**

Key words: major costs; wastewater treatment; water conservation; water-saving devices.

An economic decision rule is presented for utilities to use in recommending water-saving devices that are cost effective for homeowners. The rule takes into account the major costs (aquisition, installation, operation, maintenance, repair, and replacement) and benefits (dollar savings on water, sewer, and energy bills) associated with the installation of water-saving devices. One of these benefits, the dollar value of water savings, depends critically on water prices. An analysis of the water rate schedules of a national sample of 90 utilities indicates that, because of the widespread use of large fixed and minimum charges, homeowners' actual benefits from saving a unit of water are significantly 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 decision rule allows one to select the economically optimal device from a set of mutually exclusive alternatives, or the economically optimal combination of compatible devices for all the plumbing services in the house. The paper concludes by describing an interactive computer program that performs all the calculations needed to implement the decision rule.

**SP624;** 1982 June. 239-245. Clark, R. M.; Males, R. M.; Gates, W. E. **A water supply simulation model: Analyzing for the implications of conservation.**

Key words: analytical mathematical modeling; data base management; spatial economics; water conservation; water distribution systems; water supply simulation model.

Water conservation, as it relates to the operations of water supply systems, is not simply a problem of reducing user demand. Financing structures for water utilities are traditionally such that a reduction in demand may necessitate an increase in rates charged to the consumer, to avoid shortfalls in utility income for debt service and fixed operating expenses. In addition, a number of "beneficiaries" of the water supply system, such as those who enjoy fire protection, or those whose land is more attractive for development due to the availability of water, but who are not major consumptive users of water, tend not to bear the potential increased unit costs associated with user demand reduction.

The problem can be considered as one of spatial economics—water system customers of certain classes, located in portions of the service area, subsidize other beneficiaries of the system in other classes and areas. The impact of demand reduction, coupled with the existing financial and revenue structure, can be expected to exacerbate the existing subsidizations of water system beneficiaries. The Drinking Water Research Division of USEPA has developed a systematic approach, organized as a set of computer programs, to assist analysts in examining problems of spatial economics and physical behavior of water distribution systems. The approach, known as the Water Supply Simulation Model (WSSM), consists of a data base describing the physical, economic, and spatial characteristics of the distribution system and program modules to: create and maintain the data base; display it graphically; perform hydraulic network, time of travel, and other physical analyses; and to perform economic allocations to develop spatial cost of service. The system is general-purpose in nature, and can easily be modified to suit the needs of a specific situation. Through combination of concepts of spatial analysis, spatial economics, data base management, and analytical mathematical modeling, the WSSM provides a powerful tool for examining the consequence of alternative policies related to water supply utilities. The structure of the WSSM, and sample applications, are described.

**SP624;** 1982 June. 247-258. Hopp, W. J.; Darby, W. P. **Cost-effectiveness of potable water conservation—Multifaceted approach.**

Key words: household water conservation program; potable water conservation; wastewater treatment; wastewater treatment utilities; water supply utilities.

This study evaluates the cost-effectiveness of household water conservation measures in terms of overall economic efficiency as well as from the individual points of view of homeowners, representatives of municipal wastewater treatment utilities, and representatives of public water supply utilities. The analysis considers potential capital and operation and maintenance cost savings resulting from reduced volumes of drinking water subject to conventional, as well as conventional and granular activated

carbon, treatment processes; reduced volumes of domestic wastewater subject to secondary treatment; and reduced domestic hot water use. Evaluation is carried out using a net present equivalent which considers the time value of money as well as the effects of inflation and real price escalation. Results indicate that a household water conservation program consisting of a toilet-tank dam insert and a simple shower flow restrictor is cost-effective from all points of view considered.

**SP624;** 1982 June. 259-266. Betchart, W. B. **Municipal water conservation—A water project that pays for itself.**

Key words: benefits; costs; water conservation; water-related expenditures.

Municipal water conservation's direct economic impact is one of its most intriguing aspects. When analyzed and presented carefully, it is also one of water conservation's strongest selling points. This paper describes a structure utilized for analyzing municipal water conservation benefits and costs. The key to the structure is inclusion of all significant direct benefits and costs. Three examples of results from utilizing the analytical structure are then described.

**SP624;** 1982 June. 273-280. Konen, T. P. **Performance requirements and test procedures for water closets.**

Key words: residential water use; sanitary performance; surface cleansing; test methods; volumetric efficiency; waste removal; water closets.

Stevens Institute of Technology has completed the development of requirements and procedures for evaluating the sanitary performance of water closets. This effort was undertaken in conjunction with the U.S. Department of Commerce—National Bureau of Standards and the U.S. Department of Housing and Urban Development. The overall objective of their program is to provide technology to achieve a significant reduction in residential water use.

The objective of our study was to develop test methods for use by industry, code groups, enforcement agencies and others to determine the functional performance of water closets and thereby provide safe and efficient designs and installations. This activity has paralleled the development of the proposed revision to the American National Standard A112.19.2—Vitreous China Plumbing Fixtures. The opportunity to incorporate our findings into the product standard has added to the significance of this program.

A review of the present techniques found many of the major producers using test media spanning a wide range of size, form and density. Little information was found within the industry as to the characteristics of waste products; however, an electronic search of biology and medical journals produced several interesting studies which led to the selection of the test media. In addition to physical simulation, the media must lead to repeatable and discriminatory tests.

The primary characteristics of the water closets for which test methods and procedures were developed include: surface cleansing, waste removal, including solids and liquids, and volumetric efficiency. As a service to industry and the general public the Laboratory makes available a test kit which includes the media, instructions and data sheets.

**SP624;** 1982 June. 281-288. Baker, L. K. **Experiences and benefits of the application of minimum flow water conservation hardware.**

Key words: flow reduction; plumbing; water conservation; water fixtures; water heating facilities.

Minimum flow water conservation is achieved by using hardware and techniques specifically designed around minimizing consumption while maintaining the function, both physiological and aesthetic, of the use as opposed to modification of redesign of existing hardware and fixtures.

These techniques and hardware have been used to significantly reduce water and energy consumption and sewage treatment and disposal problems in both commercial and residential applications. This paper presents results of these applications with over an 80 percent reduction in water consumption in commercial and 60 percent in residential applications. Impacts on sewage systems have been observed and projected for both on-site and central systems. Reductions in plumbing and water heating facilities are also discussed.

The hardware discussed represents an 80 percent to 85 percent reduction when compared to conventional flow reduction techniques.

**SP624;** 1982 June. 289-292. Holycross, F. R. **Technical requirements for low-flow devices.**

Key words: appliances; fittings; fixtures; low flows; plumbing products.

There are many technical problems that we, manufacturers of plumbing products, are aware of. Low flows, pressure fluctuations, pressure regulation, solids transportation, ad infinitum. We, individually and collectively, have some answers to these problems. Some of these answers are available now, to put to use. However, there are some problems that cannot be answered because of the confusion in codes. Where a solution is good in one code area it may not apply in another area. The systems of today do not lend themselves to solutions based on new system types. We, P.M.I. and our individual companies, are ready to work toward the end of conserving water resources. We feel we have the knowledge from experience and the capabilities to contribute to the solution of "our" problem and should be in any and all discussions of the planning and resolutions of this gigantic and grave problem.

**SP624;** 1982 June. 293-326. Galowin, L. S. **A model for the transport mechanisms of solids in building pipe drains.**

Key words: building pipe drains; low water usage devices; pitch of the pipe; plumbing drainage system; plumbing fixtures; transport mechanisms; transport phenomena; wall friction.

The requirements for potable water conservation have resulted in the introduction of low water usage devices and plumbing fixtures in buildings. Reductions in the quantity of water discharged into the gravity drainage plumbing system can result in inadequate transport of wastes after entry into the drain pipes.

Currently, studies of the transient partially-filled pipe flow with solids in pitched horizontal drains include analytical modeling of the hydraulic/solids interactions and experiments to develop a data base for validation of design methods or empirical correlations applicable to pipe sizing methods for the plumbing drainage system. Initial results from the research on transport mechanisms for solids required for sweeping solids through pitched drain pipes are presented. The modeling parameters and test data for the flow characteristics, solid size, pipe diameter, and pitch of the pipes are discussed. The dependence of the transport phenomena on the depth of the wastewater stream, the length to diameter ratio of the solids, pitch of the pipe, and wall friction are identified as significant parameters. The computed results from the predictive model for the hydraulic forces are shown to be physically consistent.

**SP624;** 1982 June. 329-337. Maddaus, W. O.; Rothenberg, J. H. **Developing data for residential water savings.**

Key words: low-water-using bathroom fixtures; residential water savings; retrofitting; water conservation device.

Demonstration projects are being conducted for the U.S. Department of Housing and Urban Development (HUD) to document water savings in actual homes. Arrangements to conduct demonstration projects have been made with the City of Atlanta Bureau of Water, Denver Water Board, Los Angeles Department of Water and Power, and the Washington Suburban Sanitary Commission. Projects were selected on the basis of

estimated water savings, need for field data, cost, and other factors.

The following demonstration projects were selected: studies of contemporary and advanced low-water-using bathroom fixtures; a study of water- and energy-efficient homes; the effect of retrofitting on hot water and energy use; the effect of metering; the effect of a pressure change; a nationwide leak detection survey; nationwide surveys of water-using fixture use and shower water use characteristics; and the long-term effectiveness of retrofitting in various cities. Each project involves a test group of dwelling units, equipped with the water conservation device, and a control group for comparison. Results will be published in 1982 and 1983.

**SP624;** 1982 June. 339-346. Wilder, J. J. **How to implement a water conservation program—The Denver experience.**

**SP624;** 1982 June. 347-352. Smith, F. J. **Management information systems for water resources.**

**SP624;** 1982 June. 367-372. Jamieson, D. G.; Million, G. S. **Comparison between water conservation practices in the United Kingdom and the United States.**

Key words: demand management; supply management; Thames Water Authority; United Kingdom; water conservation practices.

During recent years, there has been a growing awareness, on both sides of the Atlantic, for the need to conserve resources. In the specific case of water conservation, there has been little exchange of information and, as a result, ideas have largely developed independently. The purpose of this paper is to draw comparisons between conservation activities as practiced in Britain and in the United States. Its intention is to cover both aspects of water conservation; namely, demand management and supply management, with a view towards acquainting the readership with British practices as adopted by the Thames Water Authority, and to suggest reasons for the differences between the United Kingdom and the United States in terms of attitude, emphasis, and outcome.

Obviously, any comparison of this nature is bound to be superficial; in this particular instance, the tenuity is compounded by our limited knowledge of American culture and practices. Nevertheless, the apparent difference in terms of per capita consumption is so marked that the lack of precise detail should be incidental.

**SP624;** 1982 June. 373-378. Seinwill, G. D. **Federal Water Resource Agency planning requirements and implications for water conservation.**

Key words: Federal Water Resource Agency; water conservation; water planning.

The 1978 executive water policy reform message was not a radical departure from earlier policy directives. However, its specificity about the role of conservation in water planning and management, its applicability to wider ranges of water activities, and its urgency for immediate response have differed from previous water policy statements.

**SP624;** 1982 June. 379-397. Galowin, L. S. **Plumbing codes—Essential in water conservation programs.**

Key words: plumbing codes; plumbing fixtures; wastewater flows; water conservation.

The development and implementation of water conservation programs requires acceptance of low water usage plumbing fixtures and devices. The installation of innovative components or modifications to existing plumbing systems for reduced water consumption are controlled by local jurisdictions through the plumbing codes.

A review of the developments leading to current plumbing code requirements is presented. The basis for development of revisions to codes and supporting standards from current research projects is discussed. Requirements are indicated for (a) current data based upon real water demand loads to update water supply pipe sizing (Hunter's Curve) and (b) the necessity to consider the impact of deterioration of performance from reduced wastewater flows in the building drainage system with expanding water conservation practices. Examples of laboratory research and field demonstrations of water conservation programs are provided.

**SP624;** 1982 June. 401-407. Robie, R. B. **Water conservation in California.**

Key words: in-school education; residential water conservation devices; water conservation; water resources planning; water system leak detection.

California's resource planning includes water conservation as a source of supply. By the year 2000, the State expects water savings of about 1.5 million cubic dekameters per year. Department of Water Resources (DWR) conservation activities are centralized in its Office of Water Conservation (OWC). Programs are in three major categories—agricultural, urban, and in-school education. The largest urban program is distribution of residential water conservation devices. By the end of 1982 all those living in homes built before water conserving fixtures became mandatory will be given devices. The Department works with other state agencies to save water, develops water conserving landscape gardens, encourages water conserving pricing, has a grant program for water system leak detection and works to build water conservation into local planning. Elementary school programs train teachers and make curriculum materials available. Education activities include a newsletter, drought and water conservation related reports and brochures. The Department reports on comparative water conservation performances of selected communities in the State.

Water conservation has been made an integral and vital element of water resources planning by the State of California. We see it as our most economical source of additional supply, and one that almost invariably results in savings of energy.

**SP624;** 1982 June. 409-412. McArdle, F. X. **The need for a new federal water policy.**

Key words: conservation management; federal water policy.

**SP624;** 1982 June. 413-417. Miller, W. H. **Local response for officials and consumers.**

**SP624;** 1982 June. 421-425. Gilbert, J. B. **A future look—What are the unknowns?.**

**SP624;** 1982 June. 427-432. Brusnighan, J. M. **Appraisal of 1978 conference case history: Do the benefits endure?.**

**SP624;** 1982 June. 433-441. Neely, L. M.; Opaleski, M. J.; Shelton, T. B.; Palmini, D. **Conservation in a noncrisis environment—Township of East Brunswick, New Jersey.**

**SP624;** 1982 June. 443-447. Butterfield, S. **Case study—In-school water conservation education program.**

Key words: conservation program; water conservation education program.

California's in-school water awareness and conservation program for kindergarten through eighth grade students offers special curriculum materials and teacher training. Children are the greatest resource of the future and must learn to be wise consumers and citizens in order to make informed decisions when adults. The program teaches water's vital role in life, and that this resource is limited. A secondary benefit occurs when children carry water conservation messages home. Materials are available for the entire kindergarten through eighth grade spectrum, and as a result of evaluations, 4–6 grade materials are

now emphasized. The program is continuous, not just a one-time informational campaign. With a small budget and staff, 10 percent of the total elementary grade population has been reached in the last three years.

One of our most successful water conservation programs and the one that has been around the longest is our in-school education program. It is a water awareness and conservation program for kindergarten through eighth grade students throughout the State that offers curriculum materials and teacher training.

**SP624;** 1982 June. 449-452. Butterfield, S. **Case study—Distribution of residential water saving devices.**

Key words: device installation programs; in-school education programs; residential water savings devices.

A state-wide program of distributing water conservation devices to residents of the State is to be completed by 1983, and to result in annual savings of about 58,000 acre-feet of water and the energy equivalent of 1.3 million barrels of oil. Savings pay for program costs in about three months. Distribution programs began in 1977 with pilot studies resulting in the present program configuration that is based on mass mailing of kits containing displacement bags and shower flow restrictors. All programs are cooperative with local agencies and tailored to local situations, and are accompanied by an advertising campaign and in-school education programs. Detailed reports on past programs are available.

**SP624;** 1982 June. 453-464. Cronk, G. E. **Results of a peak management plan for Tucson, Arizona.**

Key words: peak management; water use patterns.

Prior to the summer of 1974, the prevailing water service philosophy of the Tucson Water Utility had been to anticipate, and meet, the unmanaged peak demand requirements of the system by increased capital expenditures for expansion of the water system. The peak demand period of the summer of 1974, however, proved to be one of the driest and hottest periods on record in Tucson. The City well system proved to be incapable of consistently meeting the prolonged peak periods. This resulted in localized disruptions in service and chronic low pressures throughout the system. The experience of that summer convinced the staff of Tucson Water and their engineering consultants of the need to evaluate and reassess the original service philosophy regarding meeting future unmanaged peak demand requirements.

**SP624;** 1982 June. 465-469. Rubin, A. R. **Water conservation efforts in rural areas.**

Key words: agricultural water uses; demand reduction; drought emergency plans; educational programs; rural areas; water conservation.

North Carolina is predominantly a rural State. Recent census figures indicate that the rural counties in the eastern and western parts are growing at a more rapid rate than are the more urbanized counties in the central part of the State. Nonetheless, major population centers do lie along the interstate highway routes that link Charlotte in the west with the Raleigh-Durham area in the east. Almost half of the State's population reside in this area known as the Piedmont Crescent. Historically, the water resources base that supports these areas has been adequate; however, with increasing population pressures, rapid industrial development, concomitant industrial development pressures, agricultural water uses, and commercial uses of water, the future availability of these once plentiful water resources is now being questioned. Many of the large urban areas are engaged in some form of water conservation program that has two primary aims: raising the level of consciousness and awareness of the local residents regarding potential drought emergency plans, and focusing on a series of educational programs, mailings, slide tapes, public meetings, exhibits, etc., on routine residential, commercial, industrial, and institutional demand reduction.

**SP624;** 1982 June. 471-477. Kinghorn, G. H. **Water conservation/flow reduction in facilities planning for Salt Lake County.**

Key words: flow reductions; water conservation.

# 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.

Clifton, J. R.; Carino, N. J. **Nondestructive evaluation methods for quality acceptance of installed building materials.** *J. Res. Natl. Bur. Stand. (U.S.). 87(5):* 407-438; 1982 September-October.

Key words: building materials; concrete; evaluation; inplace testing; inspection; nondestructive testing; quality assurance.

A review of methods developed for the nondestructive evaluation (NDE) of building materials is presented. The generic features of NDE methods are discussed. This is followed by descriptions of specific methods. The principles underlying the operation of the methods are described, along with their typical applications, advantages, and limitations. A table is included summarizing the characteristics of various NDE methods.

# 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 80-2176.** Levy, J.; Petersen, S. R. **Economic efficiency in the sizing of residential heat pumps.** 1981 July. 80 p. Available from: NTIS; PB 82-179029.

Key words: benefit-cost analysis; energy conservation; equipment selection; equipment sizing; heat pump; life-cycle costs.

This report provides a methodology for determining the optimal heat pump size, in terms of heating output capacity, for residential installations having annual heating requirements significantly greater than annual cooling requirements. The optimal size heat pump is defined as the size for which total present value, life-cycle heating and cooling costs (including equipment costs) are minimized. Incremental energy savings from increasing the output capacity of the heat pump are calculated using hourly simulation models of heat pump and building performance developed at NBS. The dollar value of the incremental savings, in present-value, life-cycle terms, is then calculated and compared with incremental costs to determine the optimal heat pump size. A base case analysis of an 1800 square-foot house in the Chicago climate shows that a slightly larger heat pump size than would typically be selected for air conditioning purposes alone is optimal for the assumptions specified. A number of sensitivity analyses are performed to show the effects of changes in load size, degradation coefficients, power utilization efficiency, economic assumptions and geographic location on the optimal heat pump size.

**NBSIR 81-2233.** Stroik, J. S. **High security locking devices. A state-of-the-art report.** 1981 January. 175 p. Available from: NTIS; PB 82-165499.

Key words: characteristics; door security; entry control; hardware; installation; locking device classification; lock operation.

An investigation was made of the literature and information related to high security, internal locking devices. The purpose of this work was to identify and document the present state-of-the-art of these devices and systems used on doors. This document supports an R & D effort to develop a locking system for sensitive ordnance structure doorways that will take the place of existing surface mounted padlocks and hasps. Locking systems were investigated both overall and their subsystem components, including bolt-works, bolt-work driving subsystems, locking mechanisms and the protective envelope. Usual categories of lock types are presented, and a new combined summary of locking device classifications is suggested to act as a standard basis for future research and development of standards. This classification divides locks by their operation, installation and component characteristics. A review of the literature includes an annotated bibliography, annotated lists of standards and specifications, national organizations and locksmith schools, a selected list of manufacturers and a glossary compiled from available glossaries. An appendix includes selected samples of manufacturers' catalogue information. As a result of this investigation, the author provides specific recommendations concerning the needs of more technical study and research together with suggested development and implementation of standard test methods.

**NBSIR 81-2285.** Hurley, C. W.; Kopetka, P. A.; Kelly, G. E. **Using microcomputers to monitor the field performance of residential heat pumps.** 1981 June. 118 p. Available from: NTIS; PB 81-240608.

Key words: analog signal conditioning; data acquisition system; field data acquisition; field instrumentation; field performance of heat pumps; heat pumps; heat pump test methods; microcomputer.

Field data on the heating and cooling performance of residential heat pumps were gathered for the purpose of verifying and refining laboratory testing procedures. This report describes the procedures, instrumentation, and microprocessor-based data acquisition system (DAS) used for evaluating the field performance of three residential heat pumps located in the Washington, D.C. area. The instrumentation, signal conditioning unit and DAS are described in detail since the designs employed are applicable to future testing projects of this type in both small and large scale field studies.

To avoid the large capacities of the DAS and data reduction facility required for on-line monitoring, a strategy was developed which used the on-line microcomputer in the field to reduce and analyze the raw data and record the calculated results. This reduced the amount of recorded data to an acceptable level and thereby extended the time period between data collection.

This report discusses the selection of the heat pumps utilized in this field study and the design and selection of the instrumentation and DAS. The requirements for scanning data and recording the results are also discussed.

The basic equations and the software for processing the data at the field units and for reducing and editing the raw data disks at a central microcomputer are described. Examples of printouts taken directly at the field units and from the data disks are shown.

**NBSIR 81-2287.** Mulroy, W. J.; Kelly, G. E. **Laboratory tests of a residential unitary water-source heat pump.** 1982 November. 51 p. Available from: NTIS; PB 83-137141.

Key words: central heating equipment; cooling; heating; heating seasonal performance; heating seasonal performance factor; heat pumps; test method; water source heat pumps.

The performance of a residential heat pump was measured in the laboratory over a broad range of source water temperatures (40°F to 90°F). Tests were performed in both heating and cooling operational modes and for both steady-state and cyclic operation.

For both heating and cooling operations, the unit capacity and COP were found to be linear functions of the average of the unit source and outlet water temperatures. In heating, the unit capacity, COP, and part load performance increased with increasing water temperature. In cooling, the unit capacity, COP, and part load performance decreased with increasing water temperature. The measured degradation coefficients ranged from 0.09 to 0.21 for heating and from 0.10 to 0.18 for cooling. An appendix is included in which the effect of the degradation coefficient and of supplemental resistance heat on the unit heating and cooling seasonal performance factors is calculated.

**NBSIR 81-2339.** Brown, P. W.; Grimes, J. W., Jr. **Simulated service testing for corrosion in solar heating and cooling systems.** 1981 September. 34 p. Available from: NTIS; PB 82-179037.

Key words: corrosion; elevated temperature; heat transfer liquid degradation kinetics; simulated service test solar collector.

This study was undertaken to evaluate a proposed ASTM simulated service test methodology to evaluate corrosion or heat transfer liquid degradation. The responses of aluminum, copper, and stainless steel to conditions simulating flow and stagnation in solar collector systems were evaluated. The chemical stabilities of ethylene and propylene glycol solutions at elevated temperature were also examined.

**NBSIR 81-2352.** Steihler, R. D. **Solar energy systems—Standards for rubber hose used with liquids above their boiling points.** 1981 September. 29 p. Available from: NTIS; PB 82-174202.

Key words: glycol antifreeze stability; heat transfer liquid; hose; hose immersion test; hose specification; rubber hose; solar energy systems.

Class AT hose in ASTM Standard D 3952-80, Specification for rubber hose used in solar energy systems, is specified for use with aqueous liquids above 100°C. The lining of this hose is subjected to immersion tests at 100°C. The purpose of this study is to determine whether immersion tests in aqueous liquids above maximum service temperature are necessary in the hose standard.

The results of an interlaboratory test indicate that Class AT hose should be subjected to immersion tests above maximum service temperature. By inference, Class N hose used with a volatile heat transfer liquid at a temperature above its boiling point should be similarly tested above maximum service temperature.

The study also indicates that ASTM Reference Coolant (ethylene glycol base) is not stable at 150°C. In addition to the hose lining, the stability of the heat transfer liquid above maximum service temperature must be determined to assure satisfactory performance of the system.

A proposed revision of ASTM D 3952 is included in the report. It provides for immersion tests above maximum service temperature of Class AT and Class N hose linings used with heat transfer liquids above their boiling points.

**NBSIR 81-2357.** Christopher, P. M. **Residential solar data center: Data dictionary/directory.** 1981 September. 99 p. Available from: NTIS; PB 82-178955.

Key words: automatic data processing; data dictionary/directory; residential buildings; solar data energy system; solar heating and cooling.

The Residential Solar Data Center project staff in the Center for Building Technology, National Bureau of Standards, maintains a computerized data base containing non-instrumented residential data from the DoE/HUD Solar Heating and Cooling Demonstration Program. This document provides a dictionary of data elements collected as part of the Residential Solar Program and a directory of the specific files which contain the data elements. This data dictionary/directory was produced by a computer program written in ASCII COBOL. The automated procedure is briefly described in an appendix.

**NBSIR 81-2369.** Christopher, P. M.; Houser, A. O. **Residential solar data center: Data resources and reports.** 1981 October. 66 p. Available from: NTIS; PB 82-180845.

Key words: automatic data processing; data base; residential buildings; solar data base; solar energy systems; solar heating and cooling.

The Residential Solar Data Center (SDC) was responsible for the establishment and operation of a computerized data base containing non-instrumented residential data collected from the DoE/HUD Solar Heating and Cooling Demonstration Program. This document includes a summary of the history and background of the SDC and its role in the demonstration program, a list of the final computer reports which are available, sample pages of representative reports, and a description of the data files which comprised the solar data base.

**NBSIR 81-2372.** Wan, C. A.; Palla, R. L., Jr.; Harris, J. E. **Development of energy test methods for a dedicated water-heating heat pump.** 1982 January. 53 p. Available from: NTIS; PB 82-170069.

Key words: energy conservation; energy consumption; flow control valve; heat pump; stratification; test method; water heater.

Modifications of the DOE test procedure for water heaters "Uniform Test Method for Measuring the Energy Consumption of Water Heaters" were made to include a dedicated water heating heat pump, system equipped with a 50 gallon electric water heater tank. Also presented are laboratory tests and results which provided the basis for the test methods used. Tests included determination of recovery efficiency, standby loss, and water heater jacket loss—all under static or no-draw conditions—and a dynamic test in which water is withdrawn according to a "typical-use" schedule. Energy requirements predicted by the proposed (static) procedure were in good agreement with measured energy consumption for the dynamic test in limited testing.

**NBSIR 81-2376.** Christopher, P. M.; Charlton, L. **Residential solar data center: Grant reports.** 1981 September. 144 p. Available from: NTIS; PB 82-180910.

Key words: automatic data processing; computer reports; grant data; residential buildings; solar data base; solar energy system; solar hot water, space heating and cooling.

The Residential Solar Data Center project staff in the Center for Building Technology, National Bureau of Standards, has been responsible for the establishment and operation of a computerized data base containing non-instrumented residential data generated by the Solar Heating and Cooling Demonstration Program sponsored by the Department of Energy (DoE) and the Department of Housing and Urban Development (HUD). This document includes computer reports of data contained in the Grant file, one of six computer files comprising the data base. These reports contain data recorded on applications submitted to HUD by organizations or individual builders applying for grants to build solar energy systems in new and/or existing homes. Approximately 668 grants have been awarded in six award cycles.

**NBSIR 81-2379.** Powell, J. W.; Barnes, K. A. **Comparative analysis of economic models in selected solar energy computer programs.** 1982 January. 82 p. Available from: NTIS; PB 82-184995.

Key words: computer simulation models; Federal Life-Cycle Cost Rules; life-cycle cost analysis; net savings; solar energy computer program; solar energy economics; solar energy systems.

A variety of computer simulation models exists for the design and study of thermal performance and economic feasibility of solar domestic hot water and space heating systems. Several studies have indicated that the thermal performance algorithms contained in the different models produce similar results. However, little comparative analysis has been done of the economic algorithms in these programs.

This report compares the economic evaluation models in five computer programs widely used for analyzing solar energy systems: F-CHART 3.0, F-CHART 4.0, SOLCOST, BLAST, and DOE-2. Differences in analysis techniques and assumptions among the programs are assessed from the point of view of consistency with the Federal requirements for life-cycle costing (10 CFR Part 436), effect on predicted economic performance and optimal system size, ease of use, and general applicability to diverse system types and building types. The FEDSOL program developed by the National Bureau of Standards specifically to meet the Federal life-cycle cost requirements serves as a basis for the comparison. Results of the study are illustrated in test cases of two different types of Federally owned buildings: a single-family residence and a low-rise office building.

The study indicated that none of the programs except FEDSOL fully conformed with the Federal requirements for life-cycle cost

analysis of renewable energy projects. However, with considerable manipulation of data inputs and simplification of assumptions, they could provide similar predictions for one measure of economic performance, net present value savings.

**NBSIR 81-2380.** Petersen, S. R. **Economics and energy conservation in the design of new single-family housing.** 1981 August. 160 p. Available from: NTIS; PB 82-203639.

Key words: architecture; building design; cost-benefit analysis; economics; energy conservation; housing; insulation; space heating and cooling costs; space heating and cooling requirements.

This report investigates the extent to which certain energy conservation modifications to the envelope design of a new, single-family house are economically justified for a wide range of climates and projected energy costs. The report provides background information on those factors that give rise to space heating and cooling loads in buildings and examines in greater detail than in previous reports the thermal interdependencies within and among envelope components that can greatly affect heating and cooling loads. Economic criteria for determining a minimum life-cycle cost building envelope design are formulated and a priority-ranking method is developed to assist in the calculation of these designs. An expanded version of the NBS Load Determination Program is used to calculate the annual heating and cooling requirements and maximum heating and cooling loads for a 1200 square foot, wood-frame house having a wide range of thermal improvements in 14 geographic locations. The report also provides a methodology for interpolating these results to climatic conditions other than the 14 analyzed. The analysis demonstrates that the optimal envelope design configuration varies over a wide range depending on climate, energy costs, and modification costs.

**NBSIR 81-2393.** Liu, S. **Analysis of thermal comfort in a passive solar heated residence.** 1981 November. 45 p. Available from: NTIS; PB 82-180142.

Key words: ASHRAE Standard; asymmetric heating; collector/storage wall; comfort envelope; comfort zone; mean radiant temperature; operative temperature; passive solar; temperature drifts; thermal comfort condition; Trombe Wall.

An analytical investigation was conducted on the thermal comfort conditions in a passive solar heated residence of the popular Trombe Wall configuration. The National Bureau of Standards Load Determination Program (NBSLD) was used to simulate the indoor thermal environment of an actual passive solar residence, using the Typical Meteorological Year (TMY) weather data tape as input at three locations of different climatic conditions. The relevant thermal comfort parameters such as the space air temperature, mean radiant temperatures, operative temperatures, radiant temperature asymmetry, and temperature drifts of the occupied zone, were computed for a prime heating month, a transition month, and a prime cooling month of a typical weather year at the three locations. These parameters were analyzed in accordance with the criteria specified in the recently revised ASHRAE Comfort Standard 55-81. It was found that for the specific passive solar residence analyzed, the upper boundary of the comfort envelope can be exceeded (overheating) during a typical clear day in the transition month of April unless a change of clothing to summer wear is made during the daytime high solar radiation house. The upper boundary will be exceeded during a typical clear day in the prime cooling month of August for a person in typical summer clothing at all three locations unless the average air movement in the occupied zone is increased above the level of natural circulation, or the thermostat setting is reduced to a lower level, or both.

**NBSIR 81-2416.** Pielert, J. H.; Chapman, R. E.; Hall, W. G. **Application of an equivalency methodology to building rehabilitation: A pilot study.** 1982 January. 91 p. Available from: NTIS; PB 82-185976.

Key words: applied economics; building codes; health and safety; housing; mathematical programming; rehabilitation; renovation.

With increased emphasis on the re-use of existing buildings, new approaches must be developed to assist regulators in making code related decisions. The application of performance criteria to building rehabilitation provides flexibility in the use of technically sound design alternatives in lieu of prescriptive provisions which may be restrictive. This report presents the results of a pilot study on the application of an equivalency methodology in achieving regulatory compliance. The use of such a methodology is particularly attractive in this area because prescriptive type provisions have been shown to constrain rehabilitation activities, and in some cases, may be mutually contradictory. Regulatory requirements were chosen so as to explicitly incorporate conflicting requirements as affecting the design of windows and doors—illumination, ventilation, egress and security. The methodology is computerized to allow the selection of least-cost means of achieving compliance with these requirements. A prototypical townhouse is evaluated using the pilot equivalency methodology and optimal compliance strategies are identified and compared with the cost of prescriptive compliance. The results of the study produced potential savings ranging from 20 to 35 percent depending on the initial conditions of the building.

**NBSIR 81-2420.** Kusuda, T.; Mizuno, M.; Bean, J. W. **Seasonal heat loss calculation for slab-on-grade floors.** 1982 March. 49 p. Available from: NTIS; PB 82-182379.

Key words: building heat transfer; DoE-2 energy analysis computer program; monthly average earth temperature; thermal response factors.

In order to facilitate an efficient slab-on-grade heat transfer calculation on a comprehensive energy analysis program such as DoE-2, BLAST and NBSLD, heat transfer calculations for slab-on-grade floors are reviewed. The computational procedure based on the Lachenbruch method is studied in depth to generate monthly average temperatures at a given depth below the floor slab. The data generated by the Lachenbruch method are then used to develop a simplified procedure for determining the monthly average earth temperatures below the floor slab. These monthly average temperature data can be used for the hourly response factor analysis of floor-slab heat transfer.

**NBSIR 81-2422.** Ings, J. B.; Brown, P. W. **Factors affecting the service lives of phase change storage systems.** 1982 February. 19 p. Available from: NTIS; PB 83-137174.

Key words: crystal growth; encapsulants; failure mechanisms; nucleating agent; phase change storage; service life prediction.

Phase change storage systems currently in use or which are in the advanced stages of development are identified. Various possible modes of degradation which may affect service lives are considered. Specifically, the effects of crystal growth, crystal segregation, supercooling, corrosion and thermal decomposition are discussed. The generic basis for the development of performance tests for inorganic phase change materials is described.

**NBSIR 81-2434.** Mulroy, W. J. **Method of testing, rating and estimating the seasonal performance of ground water source heat pumps.** 1982 November. 54 p. Available from: NTIS; PB 83-137778.

Key words: central air conditioners; heat pumps; rating procedure; seasonal cost of operation; test method.

The National Bureau of Standards has made a study of the part-load and seasonal performance of residential ground water source heat pumps operating in both heating and cooling modes. This document outlines methods for testing and rating these units which account for the variation in performance due to part-load operation and change in source water temperature. A calculation procedure is presented which can be used to estimate the seasonal performance and seasonal cost of operation of residential ground water source heat pumps.

**NBSIR 81-2443.** Bales, E. L. **Plan for a round robin of hot boxes.** 1982 February. 39 p. Available from: NTIS; PB 82-183914.

Key words: ASTM C-236; calibrated and guarded hot boxes; interlaboratory round robin tests; thermal conductance of building sections.

A plan for an interlaboratory round robin series of tests sponsored by the American Society for Testing and Materials (ASTM) using calibrated or guarded hot-box equipment is described. These testing methods are designed to measure the thermal conductance of full-scale building sections such as walls, roofs and floors. Results from about 25 hot boxes in the U.S. and Canada are expected to produce improved calibration techniques and repeatability and uncertainty information useful for improving ASTM specifications.

**NBSIR 81-2448.** Roberts, W. E.; Masters, L. W.; Clark, E. J. **Effects of air mass and integration methods on results for optical property measurements of solar cover plate and absorber materials.** 1982 January. 47 p. Available from: NTIS; PB 82-165184.

Key words: air mass; ASTM E 424; integrating sphere spectrophotometer; reflectance; selected ordinate; solar absorber materials; solar cover plates; transmittance; weighted ordinate.

This study was undertaken to compare methods of calculating the transmittance of cover plate materials and the reflectance of absorber materials. Optical data were obtained for both aged and unaged test specimens using an integrating sphere spectrophotometer. The data were integrated using: (1) the weighted and selected ordinate methods in ASTM E 424, Method A, at air mass 2.0, and (2) the selected ordinate method at air mass 1.5 and 1.0. The solar reflectance and solar transmittance values calculated using the various methods are presented in this report along with discussions of the impact of the data in terms of possible revisions to ASTM E 424.

**NBSIR 81-2450.** Mahajan, B. M. **Experimental investigation of transport of discrete solids with surge flows in a 10.0 cm-diameter partially filled pipe.** 1982 January. 65 p. Available from: NTIS; PB 82-178724.

Key words: equation; flow; horizontal; motion; partially-filled pipe; slope; solid; stream-depth; surge; transport; velocity; water.

This report presents the results of a series of experiments on the transport of discrete solids with surge flows in a partially filled slightly pitched horizontal pipe. The experimental apparatus, instrumentation, and procedures are described.

The experiments were conducted using a cylindrical solid in a 10.0-cm (4-in) diameter pipe. The water surge flows were obtained by discharging different volumes of water into the pipe from a falling head open container which simulated a water closet.

For each experiment, flow induced solid velocities and stream depth histories at various locations along the length of the pipe were measured. The effects of water volume used, pipe slope, and size of the solid on the solid velocities were examined. Solid velocities were compared with the maximum water velocities estimated from the stream depth histories. Also, the distance traversed by the solids in the pipe were measured for those cases in which the solids did not clear the pipe.

The solid velocity increased with an increase in water volume used, a decrease in the size of the solid, and an increase in the pipe slope. The solid velocity in the initial reach of the pipe was less than the maximum water velocity; and the solid velocity approaches the maximum water velocity as the solid traveled downstream, except for some experiments with small water volumes.

The distance traversed by the solid increased with an increase in water volume, a decrease in the size of the solid, and an increase in the pipe slope.

The available data are too few to indicate any definitive conclusion; however, a comparison of data on solid transport in 7.6-cm (reported in a prior publication) and 10.0-cm pipe suggests that the 7.6-cm pipe may be slightly better for transport of solids with small water volumes than the 10.0-cm pipe.

**NBSIR 81-2460.** Kao, J. Y.; Snyder, W. J. **Application information on typical hygrometers used in heating, ventilating and air conditioning (HVAC) systems.** 1982 January. 43 p. Available from: NTIS; PB 83-137158.

Key words: building energy monitoring; heating, ventilating and air-conditioning controls; humidity; humidity control; humidity measurement; humidity sensor; hygrometer.

This report provides hygrometer selection information for application in heating, ventilating and air-conditioning (HVAC) systems. A general review of hygrometer literature has been provided and the most commonly used ones for HVAC are discussed. Typical hygrometer parameters are listed to indicate the type of performance that can be expected. Laboratory test results of self-regulating, salt-phase transition hygrometers are presented and discussed in detail.

**NBSIR 82-2474.** Hurley, C. W.; Ryan, J. D.; Phillips, C. W. **Performance analysis of the Jersey City total energy site: Final report.** 1982 August. 385 p. Available from: NTIS; PB 82-260381.

Key words: absorption chillers; boiler performance; central utility plant; diesel engine performance; engine-generator efficiency; environmental impact; heat recovery; total energy system.

Under the sponsorship of the Department of Housing and Urban Development (HUD), the National Bureau of Standards (NBS) gathered engineering, economic, environmental, and reliability data from a 486 unit apartment/commercial complex located on a 6.35 acre (2.6 hectare) site in Jersey City, New Jersey. The complex consists of four medium to high rise apartment buildings, a 46,000 $ft^2$ (4300 $m^2$) commercial building, a school (kindergarten through third grade), a swimming pool, and a central equipment building.

The construction of the complex was started in 1971, and a decision was made by HUD to design the central equipment building to meet both the thermal and electrical energy demands of the site. The necessary equipment was installed to recover the waste heat from diesel engines driving the generators making the central equipment building a total energy (TE) plant. Absorption type chillers were also installed in the central equipment building. This TE plant has been serving the complex since January 1974.

The National Bureau of Standards was responsible for designing and installing the instrumentation and a data acquisition system (DAS) to determine fundamental engineering data from the plant and site buildings. The DAS was put on line in April 1975. The raw data from the DAS was processed by a minicomputer at NBS to obtain a broad spectrum of engineering results. This report describes these systems and presents the appropriate data and a performance analysis of the plant and site. The analysis of the data indicates a significant savings in fuel is possible by minor modifications in plant procedures.

This report also includes the results of an analysis of the quality of utility services supplied to the consumers on the site and an analysis of a series of environmental tests made for the effects of the plant on air quality and noise. In general, these analyses reflected favorable results for the total energy plant.

Economic and energy analyses are presented for the plant as operated during the period of the study and on a comparative basis with twelve alternative system designs applicable for providing the tenants on the site with equivalent utility services. In general, although those systems utilizing the total energy concept showed a significant savings in fuel, such systems do not represent attractive investments compared to conventional systems, with fuel costs of 1977.

**NBSIR 82-2478.** Swaffield, J. A. **Application of the method of characteristics to predict attenuation in unsteady partially filled pipe flow.** 1982 March. 89 p. Available from: NTIS; PB 82-196700.

Key words: building drainage; computer model; surge attenuation; unsteady flow.

The mechanism of flow attenuation in partially filled unsteady pipe flow is presented and shown to have relevance to the design of

gravity drainage systems.

The equations defining unsteady flow in partially filled pipe are derived and shown to be capable of solution by means of the method of characteristics. This technique as a method of predicting flow depth, velocity and wave speed along a long drainage pipe at a range of pipe gradients, diameters, and roughness coefficients was tested by means of numerical examples for a series of simulations run on a digital computer. Additionally, limited experimental verification of the analysis technique is presented for the supercritical flow response to a short duration inflow surge.

Generally, the technique developed was found to be applicable to the design of drainage systems and further work is proposed to both extend the experimental verification and for the greater complexity of the multi-branched pipe system.

**NBSIR 82-2480.** Stahl, F. I.; Crosson, J. J.; Margulis, S. T. **Time-based capabilities of occupants to escape fires in public buildings: A review of code provisions and technical literature.** 1982 April. 168 p. Available from: NTIS; PB 82-212887.

Key words: emergency egress; fire protection; fire safety; human behavior in fires; human factors; Life Safety Code; means of egress.

This document reviews available technical literature pertaining to exit facility design and emergency escape provisions of the National Fire Protection Association's *Life Safety Code* (1976 Edition) in order to determine the technical support for such provisions. The report focuses on the time-based capabilities of building occupants to effect rapid evacuations, in relation to evacuation time available during fires. A number of functional criteria are examined in relation to *Code* provisions influencing the design of means of egress and fire protection and protective signalling systems for places of assembly, residential occupancies, mercantile occupancies, and business occupancies. Provisions affecting fire exit drill and building management practices are also considered. The technical literature bearing on applicable *Code* provisions is reviewed, the validity and generalizeability of findings presented in the literature are discussed, and the degree of technical support currently available for egress provisions of the *Code* are evaluated. In addition, gaps in the technical literature are identified, and recommendations regarding future research are offered. Finally, preliminary conclusions about the supportability of *Code* provisions are presented.

**NBSIR 82-2483.** Hurley, C. W.; Ryan, J. D. **Performance analysis of the Jersey City total energy site: Executive summary.** 1982 March. 60 p. Available from: NTIS; PB 82-201401.

Key words: absorption chillers; boiler performance; diesel engine performance; engine-generator efficiency; integrated utility system; total energy systems-economic and engineering analysis; waste heat recovery.

Under the sponsorship of the Department of Housing and Urban Development (HUD), the National Bureau of Standards gathered engineering and economic data from an apartment/commercial complex located on a 6.35 acre (2.6 hectare) site in Jersey City, New Jersey.

The National Bureau of Standards was responsible for instrumenting the plant and site buildings and recording engineering data utilizing an automatic data acquisition system (DAS). The DAS was put on-line in April 1975.

Economic, reliability and environmental data were also collected and analyzed by NBS in conjunction with an analysis of the engineering data. This report presents an "Executive Summary" of the final report on the performance analysis of the Jersey City Total Energy Project. The reader is encouraged to refer to that final report for further details.

The analysis of the engineering data clearly indicates a significant savings in fuel by using the total energy concept in the plant. Several areas were also identified by this analysis where minor modifications in the plant operation could result in additional fuel savings. Three of the modifications have already been incorporated in the present plant operational procedures.

**NBSIR 82-2484.** Stone, W. C. **Internal strain, deformation, and failure of large scale pullout tests in concrete.** 1982 May. 170 p. Available from: NTIS; PB 82-229147.

Key words: concrete; crack propagation; failure surface geometry; failure theory; finite element method; internal strain; laboratory testing; large scale models; mathematical model; pullout test; stress contours.

A study was performed to obtain detailed experimental data on crack propagation and internal strain distribution for the pullout test. A 12:1 scaled-up pullout test was designed, using a commercial pullout insert for the prototype dimensions, and was instrumented with small waterproof embedment strain gages so as to obtain internal strain profiles as critical locations. Two large scale specimens were tested with apex angles falling at the upper and lower bounds currently recommended in ASTM C-900. Two dimensional axisymmetric finite element analyses were performed for the two experimental specimens and the results were compared with measured strains for load stages below the onset of internal cracking. The results showed good correlation between the analytical and experimentally observed strains. The experimental data indicate that internal cracking, and the formation of the failure surface, are principally governed by the tensile strength of the concrete. The failure surface appears to have formed by 65% of ultimate load. Beyond this point, it is likely that the entire load is carried by the mechanism of aggregate interlock. Ultimate failure occurs when all aggregates mechanically bridging the failure surface pullout from the retaining cement paste. It is likely that the pullout test measures the shear strength of the cement paste or mortar which binds the concrete together.

**NBSIR 82-2487.** Jenkins, D. R.; Mathey, R. G. **Hail impact testing procedure for solar collector covers.** 1982 April. 86 p. Available from: NTIS; PB 83-104745.

Key words: hail damage; hail impact testing; hail launcher; simulated hail testing; solar collector covers; test method development.

This report presents laboratory test results which simulate hail impact on solar collector covers. The general objective of the work is to contribute to the development of a test method for evaluating the resistance of solar collector covers to this type of loading. A procedure for such testing is described as well as results obtained with ice balls impacting four typical collector cover materials. Aspects which are discussed include the preparation of ice balls, the design and operation of a launcher for ice ball propulsion, the method of mounting cover panel specimens, the selection of ice ball velocity and impact location, and techniques for failure or damage assessment.

The research results show that ice balls of consistent diameter and mass can be prepared in the laboratory. Further, both analysis and results tend to show that acceptable simulation for evaluation or testing can be achieved with normal impacts of ice balls traveling at a resultant velocity which is the vector sum of the terminal velocity and a horizontal wind component. Results for a variety of impact locations are presented and for comparison purposes, arbitrarily selected points near the collector cover boundaries appear to be a reasonable choice. Finally, it is shown that for some collector cover materials, more than one kind of failure must be considered when evaluating test results. Test data for two types of tempered glass, semirigid fiber reinforced plastic, and flexible thin plastic film covers are presented.

**NBSIR 82-2497.** Kweller, E.; Palla, R. **A test method and calculation procedure for determining annual efficiency for vented household heaters and furnaces equipped with modulating type thermostat controls.** 1982 May. 65 p. Available from: NTIS; PB 83-137166.

Key words: annual efficiency; household heaters and furnace test procedures; hydraulic thermostat control; modulating control gas-fueled; two-stage thermostat.

As annual operating efficiency of vented heating equipment is affected by burner fuel and combustion air modulation, it is important to differentiate between the various types of controls in determining annual energy requirements. Test procedures for evaluating annual efficiency have already been developed and implemented by the Department of Energy (DoE) for furnaces with single-stage thermostat control. A modified test procedure is necessary to account for operation with fuel modulation. A revised procedure which accommodates two types of fuel modulating controls has recently been developed. Tests are conducted at reduced and maximum firing rates, and along with typical derived values from a bin analysis of weather data, the fraction of the total hours for each operating mode is obtained to calculate a weighted annual efficiency. These test methods and calculation procedures are based on and are an extension to the current DoE test procedures for the single-state type of thermostat control of central warm air furnaces.

By using the procedures developed in the report, the energy savings impact of fuel modulating controls when combined with the use of modulated combustion air is evaluated. Energy savings from 6 percent to 20 percent were determined from the increase in efficiency with both fuel and combustion air modulation. Improved efficiency was dependent on the type of thermostat control and the minimum-to-maximum fuel input; i.e., turndown ratio.

**NBSIR 82-2498.** Ruberg, K. **Solar availability in cities and towns: A computer model.** 1982 March. 236 p. Available from: NTIS; PB 82-202201.

Key words: daylighting; glazing transmission; shading algorithms; solar access; solar radiation data; urban solar application.

An interactive computer program, SOLITE, has been written to determine the incident solar radiation on urban building surfaces, street surfaces and rooms facing urban street canyons. Hourly weather data and surface descriptors are interactively entered by the user. Solar radiation data are calculated with NOAA weather tape (TMY or TRY) cloud data using the Kimura/Stephenson cloud cover algorithm. SOLITE also calculates solar radiation transmission through user specified glazing assemblies. Shadows cast by surrounding buildings and overhangs are computed, as are the interreflection effects in street canyons. In addition, internal heat gains from occupants and lighting, and daylight availability on the workplane of a room are calculated. Output options include weather data summaries, incident insolation, occupant heat gain in rooms and useable hours of daylight in a room with a given occupancy. Either hourly or daily values may be specified as output.

**NBSIR 82-2522.** Jenkins, J. P.; Reed, K. A. **A comparison of unglazed flat plate liquid solar collector thermal performance using the ASHRAE Standard 96-1980 and modified BSE test procedures.** 1982 May. 34 p. Available from: NTIS; PB 82-237660.

Key words: ASHRAE Standard 96-1980; BSE; collector efficiency; unglazed collector.

This paper reviews the BSE procedure and summarizes the ASHRAE Standard 96-1980 for testing unglazed solar collectors. The ASHRAE procedure consists exclusively of outdoor testing, whereas the BSE procedure requires a combination of outdoor and indoor testing (no irradiation) to determine the collector optical and thermal loss characteristics, respectively. Two unglazed flat plate liquid solar collectors were tested according to ASHRAE Standard 96-1980 and BSE procedures and the results compared. During the indoor BSE thermal loss tests blowers were used to simulate winds of 0–3.9 m/s (0–8.72 mi/hr) to investigate the wind effect upon collector thermal losses. The results demonstrate that the differences between the BSE and ASHRAE Standard 96-1980 thermal efficiency curves were less than the uncertainty associated with the curves.

**NBSIR 82-2531.** Ings, J. B.; Brown, P. W. **An evaluation of hydrated calcium aluminate compounds as energy storage media.** 1982 July. 15 p. Available from: NTIS; PB 82-249921.

Key words: calcium-aluminum hydrates; calorimetry; dehydration; energy storage; rehydration; solar.

Calcium aluminate hydrates and calcium aluminate hydrates containing other ions were investigated to determine the feasibility of their utilization as energy storage media. A series of these compounds were fabricated and analyzed for purity. The energy liberated on hydration of each compound was measured using conduction calorimetry and the dehydration temperature was measured using differential scanning calorimetry. Of the compounds investigated $3CaO{\cdot}Al_2O_3{\cdot}3CaSO_4{\cdot}32H_2O$ liberated the largest amount of energy upon rehydration. Initially, this value was about 100 cal/gram. However, after 18 cycles of hydration and dehydration this value drops to about 70 cal/gram.

**NBSIR 82-2533.** Clark, E. J.; Kelly, C. D.; Roberts, W. E. **Solar energy systems—Standards for screening plastic containment materials.** 1982 June. 52 p. Available from: NTIS; PB 82-242454.

Key words: durability; plastic containment materials; solar energy systems; standards.

Plastic materials are being chosen more frequently for various applications in solar energy systems. Problems with materials in solar systems have indicated a need for standards to assess the performance and durability of the materials. In this investigation laboratory studies have been performed to obtain data needed to develop standards to screen plastic containment materials for the effects of heat and for compatibility with heat transfer fluids. Five absorbers, three plastic pipe materials, and three plastics used in storage applications were included. They were evaluated to assess their durability after exposure to heat aging at 100°C and 125°C and to chemical compatibility with six heat transfer fluids at room temperature and at 70°C.

The results of the laboratory tests are presented and a draft standard to screen plastic containment materials is proposed.

**NBSIR 82-2535.** Seiler, J. F.; McKnight, M. E.; Masters, L. W. **Development of a test apparatus and method for measuring adhesion of protective coatings.** 1982 July. 36 p. Available from: NTIS; PB 82-250010.

Key words: adhesion; measurement; protective coatings; test apparatus; test method.

A pneumatic test apparatus and associated test method for measuring the adhesion of coatings have been developed with particular emphasis on: 1) overcoming some of the shortcomings of existing tests; and 2) providing a method which can provide quantitative information for both laboratory and field applications.

The test apparatus utilizes compressed air to lift a stainless steel loading fixture (button) which is bonded with an adhesive to the surface of the protective coating. The rate at which the loading fixture is loaded is controlled by a precision air pressure gauge and the tensile force required to lift the button from one coating is measured. Assuming the level of adhesion of the adhesive to the coating is greater than that of the coating to the substrate, the tensile force provides a measure of the coating adhesion. Laboratory studies with two coating materials have been performed to assess the method.

This report describes the test apparatus and associated test method and presents test data obtained to date, proposed modifications to the initial test apparatus design, and additional research needs. An Instruction Manual for use of the test apparatus is included in the Appendix.

**NBSIR 82-2538.** Rennex, B. G. **Low-density thermal insulation calibrated transfer samples—A description and a discussion of the material variability.** 1982 June. 10 p. Available from: NTIS; PB 82-238346.

Key words: building insulation; energy conservation; guarded hot plate; heat flow meter; heat transfer; low-density mineral fiber; thermal conductivity; thermal resistance; thickness effect.

The National Bureau of Standards (NBS) has developed the

capability to provide thick, low-density thermal insulation calibrated transfer samples to the thermal testing community. Previous research had indicated the need to measure thermal resistance of low-density insulation samples at thicknesses up to 150 mm (6 in.). This is due to the "thickness effect," i.e., it is not possible to determine thermal resistance values at larger thicknesses based on tests at smaller thicknesses, such as at 25 mm (1 in.). There was controversy as to the magnitude of the "thickness effect." This involved the manufacturers of insulation, the United States Federal Trade Commission, and thermal test laboratories. Another factor is that the systematic errors of apparatuses which measure thermal resistance increase significantly at greater test thickness. In order to ensure better consistency among the thermal resistance apparatuses, NBS agreed to develop and provide calibrated transfer samples at thicknesses up to 150 mm (6 in.).

The calibrated transfer samples are described. The considerations that went into the selection and preparation of these low-density mineral-fiber samples are discussed. The contributions to the calibration uncertainty due to material variability are discussed and estimated to range between 1 percent and 2.5 percent.

**NBSIR 82-2539.** Margulis, S. T.; Clark, R. E. **Nontechnical summary of the final report "Optimal weatherization of low-income housing in the United States: A research demonstration project".** 1982 August. 43 p. Available from: NTIS; PB 82-260811.

Key words: Community Action Agencies; Community Services Administration; costs of residential weatherization; energy conservation; field measurement of building energy consumption; optimal weatherization.

This report summarizes in nontechnical language the nature and results of the Community Service Administration's (CSA's) Optimal Weatherization Demonstration Research Project carried out by the National Bureau of Standards (NBS). This summary draws on the final report of the field evaluation of the Demonstration, an NBS publication entitled *Optimal Weatherization of Low-Income Housing in the U.S.: A Research Demonstration Project* (NBS BSS 144). Unless stated otherwise, this report references the final report.

The CSA/NBS demonstration installed both architectural (Building shell) and mechanical systems weatherization options, and achieved, when both types of options were used, an average reduction in space heating fuel consumption of 41 percent, at an average weatherization cost of $1862 per house.

This summary report also includes abstracts of all the technical reports documenting the CSA/NBS project. Directions for ordering available reports are included.

**NBSIR 82-2540.** Ruegg, R. T.; Sav, G. T.; Powell, J. W.; Pierce, E. T. **Economic evaluation of solar energy systems in commercial buildings: Methodology and case studies.** 1982 July. 205 p. Available from: NTIS; PB 82-260456.

Key words: building econmics; commercial buildings; economic analysis; energy economics; life-cycle costing; solar energy.

This report develops a comprehensive economic optimization model for evaluating the economic feasibility of active solar energy systems to provide service hot water and combined space heating/service hot water in commercial buildings. The model is demonstrated in a number of case studies for office buildings and retail stores. Data and assumptions for use in the model are compiled for the selected case studies. Using these data, the model is applied to estimate present value net savings (or net losses) of the solar energy systems over a 20-year life cycle. Break-even values for hot water loads, solar energy system costs, and current and future energy prices are also calculated to determine the minimum conditions under which the solar energy systems become cost effective for the selected buildings. Economic optimization paths which show the optimal solar collector areas and the corresponding present value of net savings (or net losses) associated with a range of hot water loads are developed in the case studies. Sensitivity analysis is conducted for key variables. The relationship between total life-cycle costs and the solar fraction is tested for selected cities to demonstrate how net savings (net losses) change as the solar fraction is increased. In its approach, this report is of interest to solar analysts; in its results, to the solar policy, research, and building communities.

**NBSIR 82-2553.** Seiler, J. F.; Campbell, P. G. **Development of interim performance criteria for restoration coatings for porcelain enamel surfaces.** 1982 July. 56 p. Available from: NTIS; PB 82-252024.

Key words: accelerated bathtub exposure cycle; performance criteria for restoration coatings; porcelain enamel restoration; restoration coatings.

A study was performed to develop interim performance criteria for restoration coatings for porcelain enamel surfaces. The laboratory study consisted of evaluating five restortion coatings which had been applied to porcelain enamel test panels with various surface conditions. Performance characteristics of the coatings examined included appearance, adhesion, impact resistance, stain resistance and fungal resistance. Existing test methods were used in the study if appropriate methods were available. However, the laboratory studies led to the development of a new cyclic exposure test and the use of a newly developed method for measuring adhesion. Adhesion of the coatings was the performance characteristic most sensitive to change with time of exposure to the newly developed cyclic exposure test. Interim performance criteria for restoration coatings for porcelain enamel surfaces were developed, based upon the results of the laboratory study.

Additional studies are being conducted to assess the performance and durability of selected restoration coatings applied to bath tubs in public housing units. Since the field studies are not yet completed, they are not addressed in this report.

**NBSIR 82-2554.** Metz, F. E.; Pielert, J. H.; Cooke, P. W.; Walton, D. **Health and safety considerations for passive solar heated and cooled buildings.** 1982 August. 65 p. Available from: NTIS; PB 82-263336.

Key words: building regulations; buildings; energy; enforcement; health and safety; passive design; solar energy; standards.

Passive solar buildings often introduce alternative construction techniques, and new materials and applications which presently have limited guidelines concerning safe application. This report discusses research conducted to pursue the nature of health and safety considerations in application of solar passive technology to buildings and how they would be affected by current building regulatory requirements. Health and safety considerations associated with solar passive systems are discussed including: indoor air quality; structural safety; fire safety; and environmental issues such as ventilation, illumination, temperature control, humidity and noise control. The report also identifies technical issues and research needs for addressing health and safety issues in passive solar technology.

**NBSIR 82-2567.** Turner, G. **An analysis of section 2.4 through 4.14 of the GSA proposed uniform Federal accessibility standard.** 1982 August. 58 p. Available from: NTIS; PB 82-260993.

Key words: accessibility; barrier-free design; building accessibility; database analysis.

Recently, the General Services Administration (GSA) developed a draft uniform accessibility standard (the focus of this report) intended to be promulgated in conjunction with the Department of Housing and Urban Development, the Department of Defense, and the United States Postal Service. Under contract to the General Services Administration, the National Bureau of Standards (NBS), Center for Building Technology assisted in the review of part 4, sections 4.2 through and including 4.14 of the draft standard in order to determine the extent to which previously identified problems of accessibility (NBS database) were addressed by the provisions of the standard. The analysis was carried out by reviewing and classifying the provisions of the draft standard; searching the NBS data base for information relevant to the classes of provisions in the draft standard; and comparing the provisions with the NBS database.

**NBSIR 82-2580.** Kao, J. Y.; Parken, W. H.; Pierce, T. E. **Strategies for energy conservation for a large retail store.** 1982 September. 52 p. Available from: NTIS; PB 83-115543.

Key words: building control strategies; building energy conservation; building thermal performance; HVAC systems.

A comparative analysis is made of the thermal performance of selected HVAC systems and control strategies commonly employed in large retail stores. The comparisons are made for six geographical locations representing wide climatic variations within the continental United States. Hour-by-hour simulations with the BLAST computer program were used to obtain the yearly heating, cooling and fan energy consumption of a two-story large retail store. The HVAC systems simulated were constant volume reheat, variable air volume, and with direct expansion coils. The control strategies tested were dry bulb temperature economy cycle, enthalpy economy cycle, supply air temperature resetting, lowered space heating temperature, VAV zoning variations, and the combinations of these strategies. The results of these simulations were given and discussed. Substantial energy consumption differences were shown.

**NBSIR 82-2583.** Masters, L. W.; Seiler, J. F.; Roberts, W. E. **Outdoor exposure tests of solar absorptive coatings.** 1982 October. 22 p. Available from: NTIS; PB 83-124560.

Key words: absorptive coatings; accelerated laboratory exposures; degradation; outdoor exposures; simulated stagnation exposure; solar energy.

This report is a follow up to an earlier report (NBSIR 81-2232, January 1981) in which data on the performance of selected absorptive coatings in both accelerated laboratory exposures and outdoor exposures at three sites were presented. The research presented in this report focuses upon the results obtained by continuing the outdoor exposures of absorptive coatings using ASTM E781-81, Standard Practice for Evaluating Absorptive Solar Receiver Materials When Exposed to Conditions Simulating Stagnation in Solar Collectors with Cover Plates.

Comparison of the results of the outdoor exposures with those obtained in accelerated laboratory exposures indicated that 1) the accelerated exposures, as described in ASTM E744-80, Standard Practice for Evaluating Solar Absorptive Materials for Thermal Applications, provide more severe exposure conditions than outdoor exposures, and 2) the degradation processes induced by outdoor exposure are adequately addressed by the accelerated laboratory exposures.

**NBSIR 82-2585.** Rubin, A. I. **Thermal comfort in passive solar buildings—An annotated bibliography.** 1982 October. 81 p. Available from: NTIS; PB 83-133595.

Key words: ASHRAE comfort standards; asymmetric heating/comfort; behavioral studies; clothing/thermal comfort; comfort envelope; human factors; passive solar/thermal comfort; performance/thermal comfort; temperature drifts/comfort; thermal comfort.

This study consists of a selective annotated bibliography of thermal comfort research organized around major subject areas, and recommendations for future research concerned with thermal comfort in passive solar buildings. No attempt has been made to provide a comprehensive treatment of this extensive area of investigation—as this would be beyond the scope of the project under which this work was performed. Instead, the intent has been to sample the range of experimental variables and research methods employed by thermal comfort researchers—and to indicate significant findings.

The major goals for the present report are to describe the state-of-the-art of thermal comfort research and findings and to indicate the research needed to develop the information required by those responsible for specifying, designing and operating passive solar buildings.

**NBSIR 82-2591.** Park, C.; David, A. J. **Adaptive algorithm for the control of a building air handling unit.** 1982 November. 48 p. Available from: NTIS; PB 83-142042.

Key words: adaptive control; air handling unit; direct digital control; energy management and control systems; HVAC system control; parameter estimator; PI-controller; recursive least squares algorithm; self-tuning control algorithm.

The use of adaptive control algorithms was studied for microprocessor driven direct digital control of elementary heating and cooling subsystems. An algorithm was designed for digital regulation of a linear, time-invariant first-order system with a system dead time. A recursive least squares algorithm was used to estimate, on-line, the parameters of the time-invariant linear system. The parameter estimates were then used to calculate the feedback gains of a Proportional plus Integral (PI) controller.

Through computer simulations, the adaptive-parameter PI-controller was compared with a constant-parameter PI-controller. On the basis of favorable simulation results, the adaptive algorithm was implemented for direct digital control of an air handling unit in a laboratory building at the National Bureau of Standards, Gaithersburg, Maryland. The convergence of the parameter estimates and the step response proved to be satisfactory provided the system was operating in a linear or weakly non-linear region, and was in steady or quasi-steady state. By selecting a proper scale factor, improved performance may be obtained when system characteristics vary.

# 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-82-397.** Cremeans, A. H.; Hedden, R. E. **Thermal performance case studies for residential solar heating and cooling systems.** 1982 July. 165 p. Available from: NTIS; PB 82-260100.

Key words: active solar; evaluation process; hot water; passive solar; performance criteria; solar energy; thermal performance.

This document presents five case studies on thermal performance of selected solar system designs which served as a vehicle for examining the applicability of the "Draft" Performance Criteria for Solar Heating and Cooling Systems in Residential Buildings. The purpose of this document was to identify shortcomings in the draft version of the performance criteria by means of attempting to implement the criteria. Those aspects of the criteria that require revision were highlighted.

To accomplish the intended end, an engineer who was not involved with the formulation of the criteria was chosen to apply the criteria to a variety of solar energy systems. The lack of familiarity with the criteria was intended to test the ability of the criteria to be implemented by others. A variety of systems were considered since it was clear that all criteria would not be covered by a single system evaluation. Each system evaluation is presented individually in this document.

The result of this endeavor is a methodology of applying the criteria and a set of suggestions for improvements to the thermal chapter of the Performance Criteria. The methodology is explained and then applied for each criterion. Suggestions for criteria improvement are made at the end of each criterion evaluation and summarized at the end of the document.

NBS-GCR-82-398. Lindler, K. W. **National Bureau of Standards passive solar test building handbook.** 1982 August. 55 p. Available from: NTIS; PB 82-265380.

Key words: cross-section; description; passive; physical; property; sensor; solar test building.

The National Bureau of Standards Passive Solar Test Building was constructed for the class A Passive Solar Program of the U.S. Department of Energy. The Test Building is located in Gaithersburg, Maryland (39.0°N latitude, 77.3°W longitude) at an elevation of 417 ft.

The handbook provides a complete physical description of the building including floor plans and dimensions, structure, wall cross-sections, and material properties. The location of various sensors installed in and around the building is also provided.

# 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.

20809. Martin, J. W. **The analysis of life data for wood in the bending mode,** *Wood Sci. Technol.* **14,** 187-206 (1980).

Key words: durability; duration of load; life data; life distribution; reliability; service life; wood.

The applicability of a proposed procedure based on accepted, reliable, statistics was evaluated for characterizing the duration of load properties of wood in bending. By subjecting small, clear, wood specimens to several constant stress levels, it was experimentally demonstrated that the proposed procedure is capable of estimating, at an acceptable level of confidence $\delta$ the maximum service life beyond which a specified proportion $\gamma$ of the nominal population will survive. The extension of this procedure to structural sized members seems plausible, since an estimate of the short term ultimate strength for each specimen is not required. Another attribute of the procedure is that parametric estimates can be computed without failing all of the specimens; thus this should significantly reduce the duration of load test time.

20841. Mathey, R. G.; Rossiter, W. J., Jr. **A preliminary evaluation of the tensile and elongation properties of single-ply sheet roofing membrane materials,** *Proc. 2d Int. Conf. Durability of Building Materials and Components, Gaithersburg, MD, Sept. 14-16, 1981,* pp. 442-451 (National Bureau of Standards, Center for Building Technology, Washington, DC 20234, 1981).

Key words: elongation; exposure conditions; membrane properties; roofing membranes; single-ply roofing; tensile strength; test methods.

A summary is presented of the results of a preliminary evaluation of two performance properties, tensile strength, and ultimate elongation, of nineteen single-ply sheet roofing membrane materials. Also reported are the changes in mass and length of the membrane materials caused by exposure to heat. The nineteen materials represented the general categories of single-ply sheet membranes (elastomeric, plastomeric, and modified bitumens) and were typical of those used in the United States. Membrane materials included neoprene, ethylene propylene diene terpolymer, chlorosulphonated polyethylene, polyvinyl chloride, chlorinated polyethylene, and modified bitumens. The membrane materials were tested in tension before and after exposure to heat, and heat followed by ultraviolet radiation from a xenon arc. Control (unexposed) specimens were tested at 70 and 0°F and the exposed specimens were tested at 0°F. Three ASTM tensile test procedures were selected to determine the tensile and elongation properties of the membrane materials. All nineteen materials were tested according to a procedure for rubber. The plastics and modified bitumens were also tested according to procedures applicable to reinforced fabrics and bituminous roofing membranes, respectively.

20843. Rossiter, W. J., Jr.; Mathey, R. G.; Busching, H. W.; Cullen, W. C. **Cooling time of hot bitumen during built-up roofing construction,** *Proc. 2d Int. Symp. Roofs and Roofing, Brighton, England, Sept. 21-24, 1981,* pp. 489-497 (Agrément Board, London, England, 1981).

Key words: asphalt viscosity; bitumen cooling time; roofing bitumens.

The most widely accepted waterproofing system for low-sloped roofs in the United States is bituminous built-up roofing. In the construction of bituminous built-up roofing systems, hot bitumen is generally applied to roofing components such as deck, insulation, and felts in order to adhere them to each other and to form a waterproof membrane. Bitumens commonly used as waterproofing materials and adhesives in built-up membranes are asphalt and coal tar pitch.

20848. McNall, P. E., Jr. **Building ventilation measurements, predictions, and standards,** (Proc. Symp. Indoor Air Pollution, Committee on Public Health, New York Academy of Medicine, New York, NY, May 28-29, 1981), *Bull. N.Y. Acad. Med.* **57,** No. 10, 1027-1042 (Dec. 1981).

Key words: air pollution modeling; air quality; contaminant control; standards; tobacco smoke; ventilation.

This paper discusses the energy importance of reduced ventilation. The new ASHRAE Standard 62-1981, Ventilation for Acceptable Indoor Air Quality, and extensive field measurements of ventilation are discussed. A predictive model for indoor air contaminant concentrations in residences and its verification are presented and the effects of several variables are discussed. Additional research on the indoor emanation rates of contaminants which are or may be health hazards would enable the prediction of indoor contaminant levels with various control options. Such predictions could be used to verify

or refine indoor air quality standards.

**20857.** Kovacs, W. D.; Leo, E. **Cyclic simple shear of large scale sand samples: Effects of diameter to height ratio,** *Proc. Int. Conf. Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, Apr. 26-May 3, 1981,* **III,** 897-904 (University of Missouri-Rolla, Rolla, MO, 1981).

Key words: cyclic loading; dynamic test; laboratory test; sand; shear test; simple shear test; size effects.

Cyclic drained simple shear tests on a dry sand using a 12 in diameter sample with sample heights of 1, 2, and 4 in show the affect of Diameter/Height ratio on the shear modulus and percent of critical hysteretic damping at various shear strain levels. The shear modulus is found to increase with cycle number and with increasing specimen size. The D/H ratio is found to affect the shear modulus at low shear strains (<1 percent) and found to have little effect at higher shear strains and at failure. The hysteretic damping decreases for all values of shear strain tested (0.01 to 1 percent) as the cycle number and D/H ratio increases. Possible implications on design and pore pressure development are mentioned.

**20867.** Kovacs, W. D. **Results and interpretation of SPT practice study,** *ASTM Tech. Note GTJODJ* **4,** No. 3, 126-129 (Sept. 1981).

Key words: drills; in situ test; penetration tests; practice; samplers; soil tests; standard penetration tests.

Geotechnical engineers in the United States commonly use the results of the ASTM Penetration Test and Split-Barrel Sampling of Soils (D 1586) in subsurface investigations for routine foundation design. Wide variations occur in standard penetration test (SPT) results because the present standard does not address some of the variables that control the energy delivered to the sampler. Current methods of performing the SPT in the United States were surveyed and the results are reported and interpreted. The purpose of the survey was to aid in bringing current practice to a more uniform state and to provide information for the next revision of ASTM D 1586.

**20896.** Wright, R. N. **Building-related research of the U.S. National Bureau of Standards,** *Proc. Latin American Symp. "Rational Organization of Building Applied to Low-Cost Housing," Sao Paulo, Brazil, Oct. 28, 1981,* pp. 335-347 (Instituto de Pesquisas Technologicas do, Estado de S. Paulo S/A Cidade Universitaria, 05508, Sao Paulo, Brazil, 1981).

Key words: building research; equipment research; fire research; geotechnical research; illumination; structural research; thermal performance.

Building-related research and technology transfer activities at the U.S. National Bureau of Standards (NBS) are described to: assist Latin American housing and building organizations formulate building practices effective for their particular needs, provide access to potentially useful NBS research results, and identify opportunities for cooperative studies with NBS. The Performance Concept (which relates building practices explicitly to qualities required for usefulness, safety and economy) guides NBS building research. Fundamental research makes clearer and more explicit the causes and consequences of building performance qualities and provides the foundations for sustained, cumulative improvements in building practices. Practical measurement technology is developed to assist the building community in achieving intended performance qualities. Links to intermediary organizations in the building community (professional societies, trade associations, standards organizations and governmental agencies) allow a relatively small building research organization to be cognizant of the most important technical problems facing the building community, to work with other organizations to make contributions to the improvement of building practices, and to achieve application of research results in the building community.

**20903.** Park, C. **Single-zone computer model for residential furnace location analysis,** (Proc. ASHRAE 1981 Annu. Meet., Cincinnati, OH, June 28-July 1, 1981), *ASHRAE Trans.* **87,** Pt. 2, 897-920 (1981).

Key words: burner on-time; cyclic rates; dynamic simulation computer model; fuel consumption; mobile home; overall system efficiency; residential furnaces; room temperature; thermal response factors; thermostat control.

A computer model has been constructed to determine in situ performance of a fossil fuel-fired residential furnace. This single zone model deals with both the cases when the furnace is within the zone or outside of the zone.

Based upon existing computer models such as NBSLD and DEPAF, a dynamic simulation model is developed to analyze the dynamic interaction of a heating unit, a thermostat, and a building envelope. Room air temperature is evaluated every minute while the excitation of outdoor air temperature is considered every 30 minutes. Thermal behavior of the furnace is evaluated every 5 seconds. Two kinds of thermal response factors of the structure incorporate with heat balance equations.

Simulation results of indoor installation are compared with experimentally measured values. Good agreement is obtained. Energy consumptions for indoor and outdoor installations are compared. This computer model may serve as a vehicle for sensitivity analysis due to the furnace configuration, the thermostat settings, and the building structure changes.

**20911.** Stahl, F. I. **BFIRES-II: A behavior based computer simulation of emergency egress during fires,** *Fire Technol.* **18,** No. 1, 49-65 (Feb. 1982).

Key words: building codes; building fires; computer-aided design; computer simulation; emergency egress; fire research; human performance; modeling; pedestrian movement; regulatory process; simulation of human behavior.

This paper acquaints the reader with BFIRES, a computer program designed to simulate the emergency egress behavior of building occupants during fires. Use of the program is illustrated, and findings concerning the simulation's validity are presented.

**20940.** Fanney, A. H.; Thomas, W. C. **Three experimental techniques to duplicate the net thermal output of an irradiated collector array,** *Proc. 4th Annu. Conf. ASME Solar Energy Division, Albuquerque, NM, Apr. 26-29, 1982,* pp. 511-518 (The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017, Apr. 1982).

Key words: ASHRAE 95; collectors; solar domestic hot water; solar simulator; standard; test method.

A relevant and repeatable test method is required to provide a means for rating solar domestic hot water systems. The test method should be independent of the geographical location of the laboratory and the prevailing outdoor environment. Three experimental techniques which reproduce the net thermal output of a normally irradiated solar collector without the use of a solar simulator are investigated. These techniques include the use of an in-line electrical heat source only, use of a nonirradiated collector array in series with a heat source, and the use of electrical strip heaters attached to the back of nonirradiated absorber plates.

Two single-tank direct solar domestic hot water systems have been fabricated at the National Bureau of Standards to validate each experimental technique. The solar collector array of one system is subjected to outdoor meteorological conditions. The second system, used to validate the experimental techniques, is located entirely indoors. Daily tests of the solar domestic hot water system with the irradiated collector array were subsequently repeated for the laboratory system using the three experimental techniques. Based on results from several nearly clear and intermittently cloudy days, all three simulation techniques reproduce the net thermal output of the normally irradiated collector array within four percent. Pump

controller operation can be closely reproduced using two of the techniques. Advantages and limitations of each method are discussed.

**20951.** Kovacs, W. D.; Salomone, L. A. **SPT hammer energy measurement,** *Am. Soc. Civ. Eng. J. Geotech. Eng. Div.* **108,** No. GT4, 599-620 (Apr. 1982).

Key words: boring; drilling; energy; field tests; foundation design; hammer; in-situ tests; Standard Penetration Test.

A field measurement system and procedure which measures the energy delivered by a drill rig system was developed and successfully used to study the factors which affect delivered energy. Results are presented which indicate that the energy delivered by certain drill rig systems varies widely in engineering practice. The energy delivered to the drill stem varied with the number of turns of rope around the cathead, the fall height, drill rig type hammer type, and operator characteristics. The type of hammer had a strong influence on the energy transfer mechanism between the anvil and the drill stem. It appears that the safety (sleeve enclosed) hammer is more efficient in transmitting the available kinetic energy through the anvil to the drill stem than the donut hammer.

**20961.** Richtmyer, T. E.; May, W. B.; Hunt, C. M.; Hill, J. E. **Lessons from an energy-efficient test-bed,** *Build. Res. Pract.,* pp. 344-359 (Nov./Dec. 1980).

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

The Norris Cotton office building in New Hampshire, USA, is a bold design experiment to achieve year-round comfort conditions with full energy-efficiency. This interim report by staff of the US National Bureau of Standards shows how the design goal has now been virtually achieved. But the building's deliberately complex HVAC system has created control problems, with under-performance of some sub-systems. Moreover, the benefits of sophisticated building details were at first nullified by inadvertent thermal bridges.

**20995.** Hurley, W.; May, W.; Kelly, G.; Borresen, B. **Direct digital control of an air handler,** *Proc. EMCS Sixth Energy Management and Controls Society Conf., Houston, TX, Nov. 4-7, 1981,* pp. i, 1-18 (EMCS Secretariat, Driscoll & Associates, 1925 North Lynn Street, Suite 1002, Arlington, VA 22209).

Key words: building controls; digital-to-pneumatic conversion; direct digital control; energy controls; HVAC system; microprocessor control; pneumatic control system; velocity algorithm.

A microprocessor-based direct digital controller employing a PI algorithm has been used to perform local loop control on a large air handling unit in an office-laboratory building at the National Bureau of Standards in Gaithersburg, Md. The controller has successfully held the supply air temperature from the air handling unit at desired setpoints over a period of several months. Two methods used for interfacing the digital controller to the existing pneumatic control system are described. Problems encountered with air leaks in the existing pneumatic control system and their effect on the control of the supply air temperature are discussed for each type of digital-to-pneumatic interface.

The direct digital controller, which is located at the air handler, was programmed from a central microcomputer also used to monitor and record data. The softwave, PI control algorithm, and the selection of control parameters are discussed. Experimental results are presented for a number of different tests involving set-point changes and the effect of induced leaks. In addition, on-going experiments involving direct digital control of air handlers are discussed. along with a brief overview of NBS' future research program in the building controls area.

**21004.** Arens, E.; Zeren, L.; Gonzalez, R.; Berglund, L.; McNall, P. E. **A new bioclimatic chart for environmental design,** (Proc. Int. Congress, Povoa de Varzim, Portugal, May 12-16, 1980), Paper in *Building Energy Management,* E. De Oliveira Fernandes, J. E. Woods, and A. P. Faist, eds., pp. 645-657 (Pergamon Press, Great Britain, 1981).

Key words: bioclimatic chart; human comfort; indoor environment; outdoor environment; thermal comfort.

The "bioclimatic chart" developed in the 1950's by Olgyay is revised, using the latest available research on human response to the thermal environment. The chart shows the various combinations of air temperature, humidity, radiation (from the surroundings and the sun) and wind or air motion, which provide thermally acceptable conditions for average people, clothed for the average indoor winter conditions and slightly active. The chart extends the usual indoor conditions to those outdoors, with much greater differences among the thermal properties, so that indoor and outdoor conditions can be reasonably controlled for comfort purposes through architectural design or with simple mechanical equipment.

**21039.** Ichter, J. T.; Long, J. D.; Reeve, W. E.; Raufaste, N. ed. **The National Bureau of Standards: Research for defense construction,** *Mil. Eng.* **74,** No. 480, 209-211 (The Society of American Military Engineers, 607 Prince Street, P.O. Box 180, Alexandria, VA 22313-0180, May-June 1982).

Key words: building materials; building technology; construction; Department of Defense; Tri-Services Committee.

The article reviews the National Bureau of Standards' Center for Building Technology (CBT) technical assistance provided to the Department of Defense's Tri-Services Committees. For over 40 years CBT has provided the Tri-Service Committees with a technical base to improve their building design and construction practices in a variety of areas: plumbing, structures, organic coatings, wind loads, environmental effects, energy conservation, and building economics. CBT findings have resulted in material and labor savings.

**21042.** Heldenbrand, J. L.; Ross, D. K.; Stein, R. G.; Tao, W. K. Y. **Bridging the gap between component and energy performance criteria,** *Light. Des. Appl.* **12,** No. 1, 41-51 (Jan. 1982).

Key words: building energy performance; building subsystem energy criteria; energy conservation in lighting; general lighting; illumination energy; lighting energy; task lighting.

In order that building designers and builders may analyze and compare the energy (as contrasted with power or peak demand) implications of their design decisions, a method for performing the analysis and targeting the goals for the design energy consumption is needed. One approach to developing such a capability is to bridge the gap between component performance standards, such as ANSI/ASHRAE/IES 90 A, and design performance at the whole building level. A missing link is subsystem performance criteria. Development of energy performance criteria for the various energy-using subsystems would provide a common language, a goal-setting medium, information on the interactions among subsystems, and a flexible basis for conscious tradeoffs among subsystems and between the subsystems and the building envelope. This paper provides background on the need for performance-based criteria for the energy-using subsystems in buildings, describes a framework for one such approach, and illustrates its application to energy-conserving illumination subsystems for office buildings.

**21043.** Collins, B. **Window management: An overview,** *ASHRAE Trans.* **85,** No. 2, 633-640 (1979).

Key words: control; daylight; energy balance; natural ventilation; psychological needs; view out; window; window management.

Window management has been defined as the selective alteration of the window's thermal and light transmission properties. In this paper the use of window management to alter window properties is discussed in terms of the need for energy conservation in buildings. Initially, a brief review of the psychological reaction to windows is given. Then thermal calculations of the energy balance at the window

are given in terms of the use of daylight and window management. Finally, several studies on actual window management practices are reviewed. These include the use of natural ventilation, natural light, and venetian blinds. In conclusion, the need for further research into the factors that affect the use of window management is suggested, along with the urgent requirement to evaluate the window as a total system.

**21047.** Borresen, B. A. **Thermal room models for control analysis,** (Proc. ASHRAE 1981 Annu. Meet., Cincinnati, OH, June 28-July 1, 1981), *ASHRAE Trans.* **87,** Pt. 2, 251-261 (1981).

Key words: air conditioning; air distribution; building systems; computer; control; modeling; office building; thermal response; ventilation.

The analysis of a dynamic control loop often requires the use of a room model. This paper discusses four simplified dynamic room models which in different ways take into account the thermal interaction between room air and surrounding walls. The room air is assumed to be fully mixed.

It is shown that the choice of the simplification level employed depends on how closely the long-term responses and steady-state values are to fit the actual room response. For modeling short-term dynamic responses, a simple time constant corresponding to the air change rate of the room is usually adequate and will lead to choosing conservative control parameters.

An experimental procedure for determining typical parameter values is discussed.

**21048.** Borresen, B. A. HVAC **control process simulation,** (Proc. ASHRAE 1981 Annu. Meet., Cincinnati, OH, June 28-July 1, 1981), *ASHRAE Trans.* **87,** Pt. 2, 871-882 (1981).

Key words: air conditioning; building systems; computer; control; heat exchanger; modeling; monitoring; research; steam; thermal response; valve.

The modeling and simulation of HVAC systems and their controls is necessary for properly understanding the dynamic performance of heating and cooling processes in buildings. In carrying out such analyses, it is useful to distinguish between closed-loop control and steering or open-loop control. In addition, HVAC systems and controls are characterized by large working ranges. It is normal to have systems operating at low loads for a large portion of a heating or cooling season and to have to contend with large non-linearities.

This paper discusses the simulation of closed-loop control systems and develops a methodology for modeling nonlinear systems. The simulation is primarily characterized by a "chaining process" and a "transition process." In the chaining process, all the elements in the system are coupled together and all nonlinearities are accounted for. During the transition process, all the elements are decoupled, the inputs are held constant, and the outputs are calculated for one step in the future. The simulation is, therefore, not depending on solving a high number of simultaneous equations. This is especially advantageous when dealing with non-linear systems. The primary structurc of the simulation model is built up around time constants, transport delays and non-linear elements.

The usefulness of this simulation methodology is illustrated by presenting some results obtained by modeling the performance of a steam-heated air coil controlled by an adaptive control algorithm. This example includes the steam valve, steam trap, and condensate build-up in the coil, and is extremely nonlinear.

**21060.** Appleman, B. R.; Campbell, P. G. **Salt spray testing for short term evaluation of coatings. Part I: Reaction of coatings in salt spray,** *J. Coatings Technol.* **54,** No. 686, 17-25 (Mar. 1982).

Key words: coatings; salt-spray test; short-term tests.

Various aspects of short-term testing of coatings for steel are examined, with particular emphasis on the salt spray test. The salt spray test is the most widely used and the most widely criticized of the accelerated test methods. The salt spray test continuously exposes a coating to a neutral salt solution at an elevated temperature. The test excludes ultraviolet light and atmospheric pollutants. The chemical and physical consequences of this artificial environment are reviewed. The coating's ability to protect against corrosion is examined in light of the principal mechanisms (i.e., barrier, inhibitive, sacrificial). In addition, the observed and expected effects of salt spray are discussed for specific coating binder types including oil and alkyd systems, vinyls and other thermoplastic polymers, catalyzed epoxies, latexes, and zinc-rich primers.

**21081.** Galowin, L. S.; Swaffield, J. A.; Bridge, S. A. **A computational method for unsteady partially filled pipe flow and finite solid velocity transport,** *Proc. AIAA/ASME 3d Joint Thermophysics, Fluids, Plasma and Heat Transfer Conf., St. Louis, MO, June 7-11, 1982,* pp. 1-8 (American Institute of Aeronautics and Astronautics, 1290 Avenue of the Americas, New York, NY 10104, June 1982).

Key words: computational method, fluid mechanics; drainage piping; transient pipe flow; transient solid motion, pipe flows.

The unsteady flow equations defining partially filled unsteady pipe flow and solid transport were developed and shown to be capable of numerical solution by the method of characteristics. Comparisons between predicted and observed flow attenuation in pitched pipes confirmed the solution technique. A predictive model for solid transport, based upon the use of force and leakage flow relationships, provides the moving boundary condition about the solid for coupling with the method of characteristics solution for the transient analysis. Agreement between solid transport measurements and predicted results for solid velocities with input time dependent surge flow and for initiation of solid motion from rest with steady inflow was shown.

**21082.** Dikkers, R. D. **Solar energy system performance standards and criteria—NBS activities,** *Proc. Second Solar Heating and Cooling Commercial Demonstration Program Contractors' Review, San Diego, CA, Dec. 13-15, 1978,* pp. 13-23 (U.S. Department of Energy, Washington, DC 20585, July 1979).

Key words: buildings; cooling; heating; hot water; performance criteria; solar energy; standards.

One of the important objectives of the National Program for Solar Heating and Cooling of Buildings is the development of "solar energy system performance standards and criteria for the production and installation of solar energy systems, subsystems and components with appropriate provisions for consumer protection." To assist the Department of Energy (DoE) and the Department of Housing and Urban Development (HUD) in accomplishing the above objective, the National Bureau of Standards (NBS) has been actively working with standards-writing organizations, industry, designers, consumers and other members of the building community for the past few years to help develop performance criteria and standards for solar heating and cooling applications. This overview paper describes the current status and highlights of NBS activities which are being carried out with financial support from DoE and HUD.

**21106.** Dikkers, R. D. **Standards for solar energy systems,** *Proc. 1980 ASQC Technical Conf. Transactions, Atlanta, GA, May 20-22, 1980,* pp. 201-208 (American Society of Quality Control, 161 West Wisconsin Avenue, Milwaukee, WI 53203, 1980).

Key words: biomass; heating and cooling; performance criteria; photovoltaics; solar energy systems; standards; wind energy.

One of the major findings reported in the Domestic Policy Review of Solar Energy was that "limited public awareness of and confidence in solar technologies is a major barrier to accelerated solar energy use." Accordingly, President Carter has recommended that private sector and governmental activities to develop equipment performance standards, testing and certification need to be coordinated and accelerated. This paper describes some of the major program efforts which are underway in both the public and private sectors to develop and evaluate standards for various solar energy systems (heating and cooling, photovoltaics, wind, biomass). Some of the important program accomplishments are also discussed.

**21119.** Dikkers, R. D. **Passive solar standards, performance criteria and code provisions,** *Proc. U.S. Dept. of Energy Passive & Hybrid Solar Energy Program Update Meet., Washington, DC, Sept. 21-24, 1980,* pp. 2-9–2-11 (U.S. Department of Energy, Washington, DC 20585, 1980).

Key words: code provisions; passive solar systems; performance criteria; solar energy; standards; test procedures.

The development of performance standards and criteria for solar energy systems, subsystems and components is one of the key objectives identified in the Department of Energy National Program for Solar Heating and Cooling of Buildings. This paper briefly describes various standards needs, planning efforts and some of the current activities which are underway relating to passive solar standards, performance criteria and code provisions.

**21123.** Walton, G. N. **Airflow and multi-room thermal analysis,** *ASHRAE Trans. Tech. Paper No. 2704,* **88,** Pt. 2, 11 pages (1982).

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

A model for computing the infiltration and air flow between rooms of a multi-room building is presented 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 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.

**21134.** Waksman, D.; Walton, W. D. **Fire testing of solar collectors by ASTM E 108,** *Fire Technol.* **18,** No. 2, 174-187 (May 1982).

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. 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.

**21141.** Kusuda, T.; Alereza, T.; Hovander, L. **Development of equipment seasonal performance models for simplified energy analysis methods,** *ASHRAE Trans. Tech. Paper No. 2715,* **82,** Pt. 2, 13 pages (1982).

Key words: air conditioner; energy analysis; equipment performance; gas furnace; heat pump; simplified calculation.

In pursuit of development of simplified energy calculation methodologies, seasonal performance models for residential heating and cooling systems were developed. Previous studies have shown that the variable-base degree-day (VBDD) method renders results close to those generated by hourly models, such as DOE-2. However, the results included only heating and cooling loads, not the energy use. The objective of this research was to develop a method for calculation of seasonal performance of residential HVAC equipment while it could be used within the framework of variable-base degree-day method.

Using the results of DOE-2 on 60 residences representing 10 climatological conditions, seasonal performance models were developed for gas and oil furnaces, air conditioners, and heat pumps. These models utilize the heating and cooling loads calculated by VBDD, equipment specifications, and weather information, to calculate the seasonal efficiencies/COP's for residential HVAC equipment. Results obtained using these seasonal models were mainly within 5 percent of those calculated hourly by DOE-2.

**21150.** Carino, N. J.; Lew, H. S. **Re-examination of the relation between splitting tensile and compressive strength of normal weight concrete,** *ACI J. Tech. Pap., Title No. 79-23,* 214-219 (May-June 1982).

Key words: age-strength relation; building codes; compressive strength; concretes; regression analysis; safety; shear properties; splitting tensile strength; statistical analysis.

Based on statistical analyses of selected data, which included concretes with compressive strengths from 980 psi (6.9 MPa) to 5750 psi (39.7 MPa), it is shown that the commonly assumed square root of compressive strength function is not the most appropriate relation for selected data or data with a similar precision and the same range; rather, a simple power function is more applicable over a wide range of concrete strengths.

**21211.** Batts, M. E. **Probabilistic description of hurricane wind speeds,** *Am. Soc. Civ. Eng.* **108,** ST7, 1643-1647 (July 1982).

Key words: Extreme Type II; hurricanes; Weibull; windspeeds.

This note presents information on the parameters of the best fitting Weibull Distributions estimated for hurricane windspeeds simulated as described in a previous paper, and shows the effect of the incorrect assumption that an Extreme Type I distribution rather than a Weibull distribution, is the appropriate description of the extreme windspeeds.

**21212.** Simiu, E. **Thermal convection and design wind speeds,** *Am. Soc. Civ. Eng.* **108,** No. ST7, 1671-1675 (July 1982).

Key words: climatology; extreme winds; fluid mechanics; meteorology; structural engineering; wind.

Estimates are presented of the extent to which the effect of thermal convection upon wind profiles is significant in structural engineering and extreme climatological calculations. The estimates are based upon Monin and Obukhov's theory and recent experimental results reported in the meteorological literature.

**21264.** Hill, J. E.; Fanney, A. H. **A proposed procedure of testing for rating solar domestic hot water systems,** *ASHRAE Trans.* **86,** 805-822 (1980).

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

A procedure of testing for rating solar domestic hot water (SDHW) systems is currently under consideration by a project committee of the ASHRAE Standards Committee. The procedure requires that the entire SDHW system be assembled in the laboratory and that the system be subjected to specific diurnal variations of the environmental conditions controlling the system performance, such as incident solar radiation and ambient temperature, while the system supplies hot water at specified temperature, times, and draw rate throughout the day. The test continues until the system performance is near-identical for successive days. It is proposed that the rating be the daily "fractional energy savings" under this quasi-steady-state condition. The actual collector array can be used and irradiated with a solar simulator. Alternately, the collector module comprising the array can be tested separately following ASHRAE Standard 93-77, the results used to compute the thermal output of the array under the specified system test conditions, and this thermal output supplied to the system during the system test using a conventional energy source.

The purpose of this paper is to describe the proposed test procedure, suggest alternate ways the simulation of the collector array thermal output can be accomplished in the laboratory, and report on progress being made at the National Bureau of Standards to validate the procedure.

**21349.** Reed, K. A. **Instrumentation for thermal performance measurements: Striving for measurement assurance in solar collector testing,** *Proc. Fourth Annu. Conf. ASME Solar Energy Division, Albuquerque, NM, Apr. 26-29, 1982,* pp. 337-340 (The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017, Apr. 1982).

Key words: fluid flow; instrumentation; irradiance; measurements; solar; temperature.

This paper reviews the instrumentation commonly used to measure the primary physical variables needed to determine the thermal performance of active solar energy equipment, especially liquid-type solar collectors. These variables include fluid flow, temperature difference, and irradiance. Measurement techniques and difficulties are discussed, as are typical measurement uncertainties.

**21354.** Knab, L. I.; Jenkins, D. R.; Mathey, R. G. **The effect of moisture on the thermal conductance of roofing systems,** *Proc. ASHRAE/DoE Conf. Thermal Performance of the Exterior Envelopes of Buildings, Kissimmee, FL, Dec. 3-5, 1979,* pp. 816-835 (ASHRAE, 345 East 47th Street, New York, NY 10017, 1981).

Key words: built-up roofing; insulation; moisture; roofing; thermal conductance; thermal conductivity; thermal resistance.

The results of laboratory tests are presented describing the effect of moisture content on the thermal conductance of roofing systems containing insulation. Roofing systems, consisting of five types of rigid-board roof insulations with attached four-ply bituminous built-up membrane, were tested. Moisture was induced into the roofing system specimens by maintaining a constant water vapor pressure difference across them. Moisture gain in the insulation varied depending on the type and thickness of the insulation.

A procedure was developed, using a heat-flow meter apparatus (ASTM C 518 type), to carry out thermal conductance tests on roofing specimens containing moisture. More than 200 tests were performed over a wide range of moisture contents. The approximate moisture distribution in the insulation was determined from core samples.

Relationships between the thermal conductance and moisture content are presented. The relationships show that the presence of moisture in roofing systems can cause significant increases in thermal conductance, depending on the type and thickness of the insulation.

**21385.** Gross, J. **Summary of the NBS-NCSBCS Joint Conference on Building Rehabilitation Research and Technology for the 1980's,** *Proc. Building Rehabilitation Research and Technology for the 1980's, San Francisco, CA, Dec. 12, 1979,* pp. 308-312 (National Conference of States on Building Codes and Standards, Inc., 481 Carlisle Drive, Herndon, VA 22070, 1980).

Key words: building accessibility; building rehabilitation guidelines; code enforcement; earthquake requirements; energy conservation; existing buildings; rehabilitation.

This paper is the summary of a two-day technical conference, held on December 10-11, 1979, in San Francisco, California. It summarizes the twenty plus technical papers presented in four technical sessions, keynote address, and discussion of the HUD Rehabilitation Guidelines. The four technical sessions were: Building Code Development and Enforcement; Energy Conservation; Seismic Considerations and Solutions; Legal Implications and Economic Approaches.

It is to be published by the National Conference of States on Building Codes and Standards as part of the proceedings of this joint NBS-NCSBCS Conference.

**21387.** Thomas, W. C.; Dawson, A. G., III; Waksman, D.; Streed, E. R. **Determination of incident angle modifiers for flat-plate solar collectors,** *Proc. ASME Solar Energy Division Fourth Annu. Conf., Albuquerque, NM, Apr. 26-29, 1982,* W. D. Turner, ed., pp. 501-510 (American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017, 1982).

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

Existing test proceures for measuring and rating thermal performance require the determination of the angular response of collectors in order to account for non-normal incident beam irradiance. Angular response measurements for four different types of collectors, each type tested by three different laboratories, are presented and analyzed. Substantial differences, both within and between laboratories, are reported for the same type collectors. An analysis of the measurement procedure shows that experimentally determined angular response parameters are subject to relatively large uncertainties. The problem results to a large extent from measuring collector efficiencies at non-normal incident angles where measurement uncertainty is of the same order of magnitude as the efficiency reduction attributable to these off-normal angles. Other factors which can affect angular response measurements and the method of correlating results are also discussed.

A theoretical analysis shows that shading of the absorber by the collector air space side and end walls for non-normal incident angles can be of the same order of importance as the decrease in the transmittance of the cover assembly. While this situation complicates an analytical approach, it is concluded that calculations are adequate to depict the angular response of conventional flat-plate tube-in-sheet collector designs. A simplified analytical procedure and nomographs are presented for rapid calculation of incident angle modifiers.

The predicted seasonal performance of solar energy systems and clear-day ratings of typical flat-plate collectors are shown to be relatively insensitive to large uncertainties in incident angle modifiers. Typically, the values of these calculated quantities could be affected by approximately five per cent as a result of uncertainty in the test-derived angular response parameter.

**21406.** Fattal, S. G.; Reinhold, T. A.; Ellingwood, B. **Analysis of thermal stresses in internally sealed concrete bridge decks,** *Federal Highway Administration Research Report No. FHWA/RD-80/085,* 116 pages (Available from the National Technical Information Service, Springfield, VA 22161, 1981).

Key words: bridge deck; concrete; construction methods; cracking; finite element analysis; heat treatment; structural design; thermal analysis; thermal stress.

A structural analysis program is prepared to predict thermal stresses which result from the application of heat blankets to concrete decks of highway bridges. The decks are heated to obtain an internally sealed concrete so as to better protect the reinforcement from corrosion. Simple decks are first studied to determine the sensitivity of the solutions to various modeling assumptions. Two full scale bridge decks are also analyzed for which the temperature distributions are predefined on the basis of field data. The program will provide a helpful tool which will enable future field measurements to be planned more selectively. It will also provide insight on means for improving the heat treatment process so as to minimize cracking damage.

**21407.** Yaniv, S. L.; Danner, W. F.; Bauer, J. W. **Measurement and prediction of annoyance caused by time-varying highway noise,** *J. Acoust. Soc. Am.* **72,** No. 1, 200-207 (July 1982).

Key words: duration; laboratory psychoacoustics; measurement of adverse response to noise; noise criteria; noise indices; time-varying highway noise.

Twenty-eight audiologically normal adult subjects participated in a study designed to assess how well six noise-rating indices would predict the annoyance caused by 3-min recorded samples of traffic noise obtained from both nominally constant-speed and stop-and-go traffic. The study was performed in a laboratory simulating a home environment. Annoyance judgments were obtained through the use of a magnitude estimation technique involving a 10-point scale. Subjects were also asked if they could accept each of the 24 traffic sounds if

heard on a regular basis in their homes. Data obtained indicate that the simpler noise-rating indices, such as the average sound level and the level exceeded 10% of the time, predict annoyance as well as, if not better than, complicated schemes incorporating a measure of either variability or rate-of-change of levels with time. Thus it appears that the measurement and computational burdens associated with these complicated schemes are unwarranted.

**21424.** Pfrang, E. O.; Marshall, R. **Collapse of the Kansas City Hyatt Regency walkways,** *Civ. Eng.* **52,** No. 7, 65-68 (July 1982).

Key words: building; collapse; connection; construction; failure; steel; walkway.

An investigation into the collapse of two suspended walkways within the atrium area of the Hyatt Regency Hotel in Kansas City, MO, is presented in this report. The investigation included on-site inspections, laboratory tests and analytical studies.

Three suspended walkways spanned the atrium at the second, third, and fourth floor levels. The second floor walkway was suspended from the fourth floor walkway which was directly above it. In turn, this fourth floor walkway was suspended from the atrium roof framing by a set of six hanger rods. The third floor walkway was offset from the other two and was independently suspended from the roof framing by another set of hanger rods. In the collapse, the second and fourth floor walkways fell to the atrium floor with the fourth floor walkway coming to rest on top of the lower walkway.

Based on the results of this investigation, it is concluded that the most probable cause of failure was insufficient load capacity of the box beam-hanger rod connections. Observed distortions of structural components strongly suggest that the failure of the walkway system initiated in the box beam-hanger rod connection on the east end of the fourth floor walkway's middle box beam.

Two factors contributed to the collapse: inadequacy of the original design for the box beam-hanger rod connection which was identical for all three walkways, and a change in hanger rod arrangement during construction that essentially doubled the load on the box beam-hanger rod connections at the fourth floor walkway. As originally approved for construction, the contract drawings called for a set of continuous hanger rods which would attach to the roof framing and pass through the fourth floor box beams and on through the second floor box beams. As actually constructed, two sets of hanger rods were used, one set extending from the fourth floor box beams to the roof framing and another set from the second floor box beams to the fourth floor box beams.

Based on measured weights of damaged walkway spans and on a videotape showing occupancy of the second floor walkway just before the collapse, it is concluded that the maximum load on a fourth floor box beam-hanger rod connection at the time of collapse was only 31 percent of the ultimate capacity expected of a connection designed under the Kansas City Building Code. It is also concluded that had the original hanger rod arrangement not been changed, the connection capacity would have been approximately 60 percent of that expected under the Kansas City Building Code. With this change in hanger rod arrangement, the load capacity of the walkways was so significantly reduced that, from the day of construction, they had only minimal capacity to resist their own weight and had virtually no capacity to resist additional loads imposed by people.

**21429.** Brown, P. W.; Masters, L. W. **Factors affecting the corrosion of metals in the atmosphere,** *Atmos. Corros.,* pp. 31-49 (1982).

Key words: atmospheric corrosion; chlorides; particulates; relative humidity; sulfates; weathering factors.

The durability of materials is dependent, to a large extent, on the in-service environment to which they are exposed; thus, the prediction of durability requires knowledge of the service environment. Weathering factors, which comprise one group of environmental factors, are the subject of this report.

From the standpoint of assessing the resistance of a metal to atmospheric corrosion, the characterization of the in-service environment is essential. The environmental factors of importance in durability testing can be divided into factors relating to: 1) weathering, 2) biological organisms, 3) stress, 4) incompatibility, and 5) use. Weathering factors include solar radiation, temperature, water, normal air constituents, air contaminants, and wind. Biological factors are manifold and may include the effects of a variety of life forms. Stress factors may be sustained or periodic. Incompatibility factors may be due to deleterious interactions between adjoining or neighboring materials. Use factors reflect misuse or abuse and the normal wear of materials. The effects of the five classes of environmental factors are not independent and substantial interaction between them is observed.

The effects of environmental factors on atmospheric corrosion are discussed with emphasis placed on weathering factors. Climatological data along with data on the abundance of pollutants are presented.

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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).
- Miles College, C. A. Kirkendoll Learning Resource Center (1980).
- Samford University Library (1884).

Enterprise: Enterprise State Junior College, Learning Resources Center (1967).
Fayette: Brewer State Junior College, Learning Resources Center Library (1979).
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 Learning Resources Center (1963).
Troy: Troy State University Library (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).
- U.S. Department of Interior, Alaska Resources Library (1981).

Fairbanks: University of Alaska, Elmer E. Rasmuson Library (1922).
Juneau:
- Alaska State Library (1900).
- University of Alaska-Juneau Library (1981).

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 Library (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 State Library-REGIONAL. (1978).
- Arkansas Supreme Court Library (1962).
- Little Rock Public Library (1953).
- University of Arkansas at Little Rock Library (1973).
- University of Arkansas at Little Rock Law Library (1979).

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 University, 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 University Library (1963).
Bakersfield:
- California State College, Bakersfield Library (1974).
- Kern County, Beale Memorial Library (1943).

Berkeley:
- University of California, Law Library (1963).
- University of California, General Library (1907).

Carson:
- California State University, Dominguez Hills Educational 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, Shields Library (1953).
- University of California at Davis, Law Library (1972).

Downey: Downey City Library (1963).

Fresno:
California State University, Henry Madden 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, College 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 Marymount University, Charles Von der Ahe Library (1933).
Loyola Law School, Law Library (1979).
Occidental College Library (1941).
Pepperdine University Library (1963).
Southwestern University, School of Law Library (1975).
University of California at Los Angeles Research Library (1932).
University of California, Los Angeles, Law Library (1958).
University of Southern California Library (1933).
University of Southern California, Law Library (1978).
U.S. Court of Appeals, 9th Circuit Library (1981).
Whittier College, School of Law Library (1978).
Menlo Park: Department of 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, Oviatt Library (1958).
Norwalk: Norwalk Public Library (1973).
Oakland:
Mills College Library (1966).
Oakland Public Library (1923).
Ontario: Ontario City Library (1974).
Palm Springs: Palm Springs Public Library (1980).
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 Library (1962).
University of San Diego, Kratter 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 University, J. 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 Polytechnic State 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, McHenry Library (1963).
Santa Rosa: Sonoma County 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 College, Stanislaus Library (1964).
Vallejo: Solano County, John F. Kennedy Library (1982).
Valencia: Valencia Regional Library (1972).
Ventura: Ventura County Library (1975).
Visalia: Tulare County Free Library (1967).
Walnut: Mount San Antonio College Library (1966).
West Covina: West Covina Regional Library (1966).
Whittier: Whittier College, Wardman Library (1963).

## CANAL ZONE

Balboa Heights: Panama Canal Commission, Library Services Branch (1963).

## COLORADO

Alamosa: Adams State College, Learning Resources Center (1963).
Boulder: University of Colorado at Boulder, Government Publications Library (1879)-REGIONAL.
Colorado Springs:
Colorado College, Tutt Library (1880).
University of Colorado at Colorado Springs, Library (1974).
Denver:
Auraria Library (1978).
Colorado State Library (unknown).
Colorado Supreme Court Library (1978).
Denver Public Library (1884)-REGIONAL.
Department of the Interior, Water and Power Resources Service 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 Library (1968).
Pueblo:
Pueblo Library District (1893).
University of Southern Colorado Library (1965).
U.S. Air Force Academy: Academy Library (1956).

## CONNECTICUT

Bridgeport:
Bridgeport Public Library (1884).
University of Bridgeport School of Law Library (1979).
Danbury: Western Connecticut State College, Ruth A. Haas Library (1967).
Danielson: Quinebaug Valley Community College Library (1975).
Enfield: Enfield Central Library (1967).
Hartford:
Connecticut State Library (unknown)–REGIONAL.
Hartford Public Library (1945).
Trinity College Library (1895).
Middletown: Wesleyan University, Olin Library (1906).
Mystic: Mystic Seaport Museum 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 Law Library (1981).
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, Peterson Library (1971).

## DELAWARE

Dover:
Delaware State College, William C. Jason Library (1962).
State Law Library in Kent County (unknown).
Georgetown:
Delaware Technical and Community College Library (1968).
Sussex County Law Library (1976).
Newark: University of Delaware Library (1907).
Wilmington:
Delaware Law School Library (1976).
New Castle County Law Library (1974).

## DISTRICT OF COLUMBIA

Washington:
Administrative Conference of the United States Library (1977).
Advisory Commission on Intergovernmental Relations Library (1972).
Catholic University of America, 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 and Human Services (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 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 Court of Appeals Library (1981).
District of Columbia Public Library (1943).
Executive Office of the President, Office of Administration Library and Information Service Division (1965).
Federal Deposit Insurance Corporation Library (1972).
Federal Election Commission Library (1975).
Federal Labor Relations Authority Law Library (1982).
Federal Mine Safety & Health Review Commission Library (1979).
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, Serial and Government Publications (1977).
Merit Systems Protection Board Library (1979).
National Defense University Library (1895).
University of the District of Columbia Library (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. Senate Library (1979).
U.S. Supreme Court Library (1978).
Veterans' Administration, Central Office Library (1967).

## FLORIDA

Boca Raton: Florida Atlantic University, S. E. Wimberly Library (1963).
Clearwater: Clearwater Public Library (1972).
Coral Gables: University of Miami Library (1939).
Daytona Beach: Volusia County Library Center (1963).
De Land: Stetson University, duPont-Ball Library (1887).
Fort Lauderdale:
Broward County Library (1967).
Nova University Law Library (1967).
Fort Pierce: Indian River Community College Library (1975).
Gainesville:
University of Florida, College of Law Library (1978).
University of Florida Libraries (1907)–REGIONAL.
Jacksonville:
Haydon Burns Library (1914).
Jacksonville University, Swisher Library (1962).
University of North Florida, Thomas G. Carpenter 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: University of Central Florida Library (1966).
Palatka: St. Johns River Community College Library (1963).
Pensacola: University of West Florida, John C. Pace Library (1966).
Port Charlotte: Charlotte County Library System (1973).
St. Petersburg:
- St. Petersburg Public Library (1965).
- Stetson University College of Law, Charles A. Dana Library (1975).

Sarasota: Selby Public Library (1970).
Tallahassee:
- Florida Agricultural and Mechanical University, Coleman Learning Resources Center (1936).
- Florida State University, College of Law Library (1978).
- Florida State University, Robert M. Strozier 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 Center, Robert W. Woodruff Library (1962).
- Emory University, Woodruff Library (1928).
- Emory University, School of Law Library (1968).
- Georgia Institute of Technology, Price Gilbert Memorial Library (1963).
- Georgia State Library (unknown).
- Georgia State University, William Russell Pullen Library (1970).
- U.S. Court of Appeals, 5th Circuit Library (1980).

Augusta: Augusta College, Reese Library (1962).
Brunswick: Brunswick-Glynn County Regional Library (1965).
Carrollton: West Georgia College, Irene Sullivan Ingram 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: 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).
Mangilao: University of Guam, Robert F. Kennedy Memorial Library (1978).

## HAWAII

Hilo: University of Hawaii at Hilo Library (1962).
Honolulu:
- Hawaii Medical Library, Inc. (1968).
- Hawaii State Library (1929).
- Municipal Reference & Records Center (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 Regional 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, 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, Law Library (1979).
- Field Museum of Natural History Library (1963).
- Illinois Institute of Technology, Chicago-Kent College of Law Library (1978).
- Illinois Institute of Technology, Kemper Library (1982).
- John Crerar Library (1909).
- John Marshall Law School Library (1981).
- 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).
Des Plaines: Oakton Community College, Learning Resource Center (1976).
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: Northern Illinois University, College of Law Library (1978).
Jacksonville: MacMurray College, Henry Pfeiffer Library (1957).
Kankakee: Olivet Nazarene College, Benner Library and Learning Resource 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).
Macomb: Western Illinois University Libraries (1962).
Moline: Black Hawk College, Learning Resources Center (1970).
Monmouth: Monmouth College, Hewes Library (1860).
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, Rebecca Crown Library (1966).
Rockford: Rockford Public Library (1895).
Romeoville: Lewis University Library (1952).
Springfield: Illinois State Library (unknown)-REGIONAL.
Streamwood: Poplar Creek Public Library District (1980).
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, Helmke Library (1965).
- Allen County Public Library (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, Duggan Library (1892).
Huntington: Huntington College, Loew Alumni Library (1964).
Indianapolis:
- Butler University, Irwin Library (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).
- Indiana University-Purdue University Library (1979).

Kokomo: Indiana University at Kokomo, Learning Resource Center (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, Law Library (1978).

## IOWA

Ames: Iowa State University Library (1907).
Cedar Falls: University of Northern Iowa Library (1946).
Council Bluffs:
- Free Public Library (1885).
- Iowa Western Community College, Herbert Hoover 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 of Iowa (unknown).

Dubuque:
- Carnegie-Stout Public Library (unknown).
- Loras College, Wahlert Memorial Library (1967).

Fayette: Upper Iowa University, Henderson-Wilder Library (1974).
Grinnell: Grinnell College Library (1874).
Iowa City:
- University of Iowa College of Law, 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 Library, North Campus (1965).
Baldwin City: Baker University, Collins Library (1908).
Colby: Colby Community College, H. F. Davis Memorial Library (1968).
Emporia: Emporia State University, William Allen White Library (1909).
Fort Scott: Fort Scott Community College, Learning Resources Center Library (1979).
Hays: Fort Hays State University, Forsyth Library (1926).
Hutchinson: Hutchinson Public Library (1963).
Lawrence:
- University of Kansas, Law Library (1971).
- University of Kansas, Watson Library (1869)-REGIONAL.

Manhattan: Kansas State University, Farrell Library (1907).
Pittsburg: Pittsburg State University, Leonard H. Axe 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 Ablah Library (1901).

## KENTUCKY

Ashland: Boyd County Public Library (1946).

Barbourville: Union College, Abigail E. Weeks Memorial Library (1958).
Bowling Green: Western Kentucky University, Helm-Cravens Graduate Center and Library (1934).
Danville: Centre College, Grace Doherty Library (1884).
Fort Mitchell: Thomas More College Library (1970).
Frankfort:
Kentucky Department of Libraries and Archives (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, Ekstrom Library (1925).
University of Louisville, Law Library (1975).
Morehead: Morehead State University, Camden-Carroll Library (1955).
Murray: Murray State University, Waterfield Library (1924).
Owensboro: Kentucky Wesleyan College Library Learning Center (1966).
Richmond: Eastern Kentucky University, John Grant Crabbe Library (1966).

## LOUISIANA

Baton Rouge:
Louisiana State Library (1976).
Louisiana State University, Middleton Library (1907)-REGIONAL.
Louisiana State University, Paul M. Herbert Law Center Library (1929).
Louisiana State University Library (1907)-REGIONAL.
Southern University Law School Library (1979).
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 Library (1938).
Lake Charles: McNeese State University, Lether E. Frazar Memorial Library (1941).
Monroe: Northeast Louisiana University, Sandel Library (1963).
Natchitoches: Northwestern State University, Watson Memorial Library (1887).
New Orleans:
Law Library of Louisiana (unknown).
Loyola University Library (1942).
Loyola University, Law Library (1978).
New Orleans Public Library (1883).
Our Lady of Holy Cross College Library (1982).
Southern University in New Orleans Library (1962).
Tulane University, Howard-Tilton Memorial Library (1942).
Tulane University Law Library (1976).
University of New Orleans Earl K. Long Library (1963).
U.S. Court of Appeals, Fifth Circuit Library (1973).
Pineville: Louisiana College, Richard W. Norton Memorial Library (1969).
Ruston: Louisiana Technical University, Prescott Memorial Library (1896)-REGIONAL.
Shreveport:
Louisiana State University at Shreveport Library (1967).
Shreve Memorial Library (1923).
Thibodaux: Nicholls State University, Ellender Memorial 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, George and Helen Ladd 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/Learning Resources Center (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, University Library (1973).
University of Baltimore Law Library (1980).
University of Maryland School of Law, Marshall Law Library (1969).
Bel Air: Harford Community College Library (1967).
Beltsville: Department of Agriculture, National Agricultural Library (1895).
Bethesda: Department of Health and Human Services, National Library of Medicine (1978).
Catonsville: University of Maryland, Baltimore County, University Library (1971).
Chestertown: Washington College, Clifton 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 Rogers Library (1966).
Towson State University, Cook Library (1979).
Westminster: Western Maryland College, Hoover Library (1886).

## MASSACHUSETTS

Amherst:
Amherst College Library (1884).
University of Massachusetts, Goodell Library (1907).
Belmont: Belmont Memorial Library (1968).
Boston:
Boston Athenaeum Library (unknown).
Boston Public Library (1859)-REGIONAL.
Boston University School of Law, Pappas Law Library (1979).
Northeastern University Dodge Library (1962).
State Library of Massachusetts (unknown).
Suffolk University, Law Library (1979).
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).
Harvard Law School Library (1981).
Massachusetts Institute of Technology Libraries (1946).
Chestnut Hill: Boston College, Bapst Library (1963).
Chicopee: College of Our Lady of the Elms, Alumnae 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 Levin Library (1972).
New Bedford: New Bedford Free Public Library (1858).
Newton Centre: Boston College Law School 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, 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, Lamar Soutter Library (1972).
Worcester Public Library (1859).

## MICHIGAN

Albion: Albion College, Stockwell Memorial Library (1966).
Allendale: Grand Valley State College, Zumberge Library (1963).
Alma: Alma College Library (1963).
Ann Arbor:
University of Michigan, Harlan Hatcher Library (1884).
University of Michigan, 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 (1978).
Wayne State University, G. Flint Purdy Library (1937).
Wayne State University, Arthur Neef Law Library (1971).
Dowagiac: Southwestern Michigan College, Matthews Library (1971).
East Lansing: Michigan State University Library (1907).
Farmington Hills: Oakland Community College, Martin L. King Learning Resources Center, (1968).
Flint:
Flint Public Library (1967).
University of Michigan-Flint Library (1959).
Grand Rapids:
Calvin College & Seminary Library (1967).
Grand Rapids Public Library (1876).
Houghton: Michigan Technological University Library (1876).
Jackson: Jackson District Library (1965).
Kalamazoo:
Kalamazoo Public Library (1907).
Western Michigan University, Dwight B. Waldo Library (1963).
Lansing:
Michigan State Library (unknown)-REGIONAL.
Thomas M. Cooley Law School Library (1978).
Livonia: Schoolcraft College Library (1962).
Madison Heights: Madison Heights Public Library (1982).
Marquette: Northern Michigan University, Olson 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).
Sault Ste. Marie: Lake Superior State College, Kenneth Shouldice Library (1982).
Traverse City: Northwestern Michigan College, Mark Osterlin Library (1964).
University Center: Delta College Learning Resources Center (1963).
Warren: Warren Public Library, Arthur J. Miller Branch (1973).
Wayne: Wayne Oakland Federated Library System (1957).
Ypsilanti: Eastern Michigan University Library (1965).

## MICRONESIA

Community College of Micronesia Library (1982).

## MINNESOTA

Bemidji: Bemidji State University, A. C. Clark Library (1963).
Collegeville: St. John's University, Alcuin Library (1954).
Duluth: Duluth Public Library (1909).
Mankato: Mankato State University, Memorial Library (1962).
Minneapolis:
Anoka County Library (1971).
Hennepin County Libraries (1971).
Minneapolis Public Library (1893).
University of Minnesota, Law School Library (1978).
University of Minnesota, Wilson Library (1907)-REGIONAL.
Moorhead: Moorhead State University Library (1956).
Morris: University of Minnesota, Morris, Rodney Briggs Library (1963).
Northfield:
Carleton College Library (1930).
St. Olaf College, Rolvaag Memorial Library (1930).
St. Cloud: St. Cloud State University, Learning Resources Center (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).
St. 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).
Columbus: Mississippi State University for Women, John Clayton Fant Memorial Library (1929).
Hattiesburg: University of Southern Mississippi, Joseph A. Cook Memorial Library (1935).
Jackson:
Jackson State University, Henry Thomas Sampson Library (1968).
Millsaps College, Millsaps-Wilson Library (1963).
Mississippi College, School of Law Library (1977).
Mississippi Library Commission (1947).
Mississippi State 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, Law Library (1967).

## MISSOURI

Cape Girardeau: Southeast Missouri State University, Kent Library (1916).
Columbia:
University of Missouri at Columbia Library (1862).
University of Missouri-Columbia, 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-Kansas City, Leon E. Bloch Law Library (1978).
Kirksville: Northeast Missouri State University, Pickler Memorial Library (1966).
Liberty: William Jewell College, Charles F. Curry Library (1900).
Maryville: Northwest Missouri State University, Wells Library (1982).
Rolla: University of Missouri-Rolla, Curtis Laws Wilson Library (1907).
St. Charles: Lindenwood Colleges, 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 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 Renne Library (1907).
Butte: Montana College of Mineral Science and Technology Library (1901).
Havre: Northern Montana College Library (1980).
Helena:
Carroll College Library (1974).
Montana Historical Society Library (unknown).
Montana State Library (1966).
State Law Library of Montana (1977).
Missoula: University of Montana Maurene & Mike Mansfield Library (1909)-REGIONAL.

## NEBRASKA

Blair: Dana College, Dana-LIFE Library (1924).
Crete: Doane College, Perkins Library (1944).
Fremont: Midland Lutheran College Luther Library (1924).
Kearney: Kearney State College, Calvin T. Ryan Library (1962).
Lincoln:
Nebraska Library Commission (1972)-REGIONAL.
Nebraska State Library (unknown).
University of Nebraska-Lincoln, College of Law Library (1981).
University of Nebraska-Lincoln, D. L. Love Memorial Library (1907)-REGIONAL.
Omaha:
Creighton University, Alumni Memorial Library (1964).
Creighton University Law Library (1979).
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. Conn Library (1970).

## NEVADA

Carson City:
Nevada State Library (unknown).
Nevada Supreme Court Library (1973).
Las Vegas:
Clark County Library District (1974).
University of Nevada at Las Vegas, James Dickinson Library (1959).
Reno:
National Judicial College, Law Library (1979).
Nevada Historical Society Library (1974).
University of Nevada Library (1907)-REGIONAL.
Washoe County Library (1980).

## 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 Danforth 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: Bloomfield Public Library (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).
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:
Jersey City Public Library (1879).
Jersey City State College, Forrest A. Irwin Library (1963).
Lawrenceville: Rider College, Franklin F. Moore 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 Alexander Library (1907).
Newark:
Newark Public Library (1906)-REGIONAL.
Rutgers, The State University, John Cotton Dana Library (1966).
Rutgers, The State University, Law School, Newark, Justice Henry E. Ackerson Law Library (1979).
Seton Hall University School of Law Library (1979).
Passaic: Passaic Public Library (1964).
Pemberton: Burlington County College Library (1979).
Phillipsburg: Phillipsburg Free Public Library (1976).
Plainfield: Plainfield Public Library (1971).
Pomona: Stockton State College Library (1972).
Princeton: Princeton University Library (1884).
Randolph Township: County College of Morris Sherman H. Masten Learning Resource Center (1975).
Rutherford: Fairleigh Dickinson University, Messler Library (1953).
Shrewsbury: Monmouth County Library (1968).
South Orange: Seton Hall University, McLaughlin Library (1947).
Teaneck: Fairleigh Dickinson University, Teaneck/Hackensack Campus Library (1963).
Toms River: Ocean County College, Learning Resources Center (1966).
Trenton:
New Jersey State Library (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 Beach: 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, General 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, Golden Library (1962).
Santa Fe:
New Mexico State Library (1960)-REGIONAL.
New Mexico Supreme Court Law Library (unknown).
Silver City: Western New Mexico University, Miller Library (1972).

## NEW YORK

Albany:
Albany Law School Library (1979).
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, Glenn G. Bartle 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, Stephen B. Luce Library (1947).
Brooklyn:
Brooklyn College Library (1936).
Brooklyn Law School Library (1974).
Brooklyn Public Library (1908).
Polytechnic Institute of New York, Spicer Library (1963).
Pratt Institute Library (1891).
State University of New York, Downstate Medical Center Library (1958).
Buffalo:
Buffalo and Erie County Public Library (1895).
State University of New York at Buffalo, 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).
Cheektowaga: Cheektowaga Public Library, Reinstein Memorial Branch (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).
Douglaston: Cathedral College Library (1971).
East Islip: East Islip Public Library (1973).
Elmira: Elmira College, Gannett Tripp Learning Center (1956).
Farmingdale: State University of New York at Farmingdale Library (1917).
Flushing: Queens College, Paul Klapper Library (1939).
Garden City: Adelphi University, Swirbul 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, Everett Needham Case Library (1902).
Hempstead:
Hofstra University Library (1964).
Hofstra University, School of Law Library (1979).
Ithaca:
Cornell University Library (1907).
Cornell Law Library (1978).
New York State College of Agriculture and Human 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 Library (1962).
Long Island City: Fiorello H. LaGuardia Community College Library (1981).
Mount Vernon: Mount Vernon Public Library (1962).
New Paltz: State University College at New Paltz, Sojourner Truth Library (1965).
New York City:
Cardoza Law School Library (1979).
City University of New York, City College Library (1884).
College of Insurance Library (1965).
Columbia University Libraries (1882).
Columbia University, School of Law Library (1981).
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 Law School Library (1979).
New York Public Library, Astor Branch (1907).
New York Public Library, Lenox Branch (1884).
New York University Law Library (1902).
New York University, Elmer Holmes Bobst Library (1967).

U.S. Court of Appeals, Second Circuit Library (1976).
Yeshiva University, Pollack Library (1979).
Newburgh: Newburgh Free Library (1909).
Niagara Falls: Niagara Falls Public Library (1976).
Oakdale: Dowling College Library (1965).
Oneonta: State University College at Oneonta, James M. Milne Library (1966).
Oswego: State University College at Oswego, Penfield Library (1966).
Plattsburgh: State University College at Plattsburgh, Benjamin F. Feinberg Library (1967).
Potsdam:
Clarkson College of Technology, Harriet Call Burnap Memorial Library (1938).
State University College at Potsdam, Frederick W. Crumb Memorial Library (1964).
Poughkeepsie: Vassar College Library (1943).
Purchase: State University of New York, College at Purchase Library (1969).
Rochester:
Rochester Public Library (1963).
University of Rochester Rush Rhees 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).
SUNY College of Technology Library (1977).
West Point: U.S. Military Academy Cadet Library (unknown).
White Plains: Pace University, Law School 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, D. Hiden Ramsey Library (1965).
Boiling Springs: Gardner-Webb College, Dover Memorial 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, Wilson Library (1884)-REGIONAL.
University of North Carolina 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, Law Library (1979).
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, J. Y. Joyner 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 Library (1971).
North Dakota Supreme Court Law Library (unknown).
State Historical Society of North Dakota Library (1907).
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 Law School Library (1980).
Capital University Library (1968).
Ohio State University Libraries (1907).
Ohio Supreme Court Law Library (1973).
Public Library of Columbus and Franklin County (1885).
State Library of Ohio (unknown)–REGIONAL.
Dayton:
Dayton and Montgomery County Public Library (1909).
University of Dayton, Roesch 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 Libraries, William H. Doane Library (1884).
Hiram: Hiram College, Teachout-Price Memorial Library (1874).
Kent: Kent State University Libraries (1962).
Marietta: Marietta College, Dawes Memorial Library (1884).
Marion: Marion Public Library (1979).
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, King Library (1909).
Portsmouth: Portsmouth Public Library (unknown).
Rio Grande: Rio Grande College and Community College, Jeanette Albiez Davis Library (1966).
Springfield: Warder Public Library (1884).
Steubenville:
Public Library of Steubenville and Jefferson County (1950).
College of Steubenville, Starvaggi Memorial Library (1971).
Tiffin: Heidelberg College, Beeghly Library (1964).
Toledo:
Toledo-Lucas County Public Library (1884).
University of Toledo, College of Law Library (1981).
University of Toledo Library (1963).
Westerville: Otterbein College Courtright Memorial 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 Oklahoma State 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 Libraries, Bizzell Memorial Library (1893).
University of Oklahoma, 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)–REGIONAL.
Tahlequah: Northeastern Oklahoma State University, John Vaughan Library (1923).
Tulsa:
Tulsa City-County Library System (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 Law Library (1979).
University of Oregon Library (1883).
Forest Grove: Pacific University, Harvey W. Scott Library (1897).
Klamath Falls: Oregon Institute of Technology, Learning and Resources Center (1982).
La Grande: Eastern Oregon College, Walter M. Pierce Library (1954).
McMinnville: Linfield College, Northup Library (1965).
Monmouth: Western Oregon State College Library (1967).
Portland:
Lewis and Clark College, Aubrey R. Watzek Library (1967).
Library Association of Portland (1884).
Northwestern School of Law, Paul L. Boley Law Library (1979).
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 Area Public Library (1969).
Bethel Park: Bethel Park Public Library (1980).
Bethlehem: Lehigh University Libraries, Linderman Library (1876).
Blue Bell: Montgomery County Community College, Learning Resources Center (1975).
Bradford: University of Pittsburgh at Bradford (1979).
Carlisle:
Dickinson College, Boyd Lee Spahr Library (1947).
Dickinson School of Law, Sheeley-Lee Law Library (1978).
Cheyney: Cheyney State College, Leslie Pinckney 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 County Library System (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).
Millersville: Millersville State College, Helen A. Ganser Library (1966).
Monessen: Monessen Public Library (1969).
New Castle: New Castle Public Library (1963).
Newtown: Bucks County Community College Library (1968).
Norristown: Montgomery County-Norristown Public Library (1969).
Philadelphia:
- Drexel University Library (1963).
- Free Library of Philadelphia (1897).
- St. Joseph's University, Drexel Library (1974).
- Temple University, Paley Library (1947).
- Temple University Law Library (1979).
- Thomas Jefferson University, Scott Memorial Library (1978).
- U.S. Court of Appeals, Third Circuit Library (1973).
- University of Pennsylvania, Biddle Law Library (1974).
- University of Pennsylvania Library (1886).

Pittsburgh:
- Allegheny County Law Library (1977).
- Carnegie Library of Pittsburgh, Allegheny Regional Branch (1924).
- Carnegie Library of Pittsburgh (1895).
- Duquesne University Law Library (1978).
- La Roche College, John J. Wright Library (1974).
- University of Pittsburgh, Hillman Library (1910).
- University of Pittsburgh 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, Bailey Library (1965).
Swarthmore: Swarthmore College Library (1923).
University Park: Pennsylvania State University Libraries (1907).
Villanova: Villanova University Law School, Pulling Law Library (1964).
Warren: Warren Library Association, Warren Public Library (1885).
Washington: Washington and Jefferson College, U. Grant Miller 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, Schmidt 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 Law Library (1979).
- 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).
- College of Charleston, Robert Scott Small Library (1869).

Clemson: Clemson University Library (1893).
Columbia:
- Benedict College, Payton 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, Kimbel 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 Resource Center (1969).
- Sioux Falls Public Library (1903).

Spearfish: Black Hills State College Library Learning Center (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:
- Public Libraries Knoxville-Knox County, Lawson McGhee Library (1973).
- University of Tennessee at Knoxville, James D. Hoskins Library (1907).
- University of Tennessee 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, Cecil C. Humphreys School of Law Library (1979).
- Memphis State University, John W. Brister Library (1966).

Murfreesboro: Middle Tennessee State University, Todd Library (1912).
Nashville:
- Fisk University Library (1965).
- Public Library of Nashville and Davidson County (1884).
- Tennessee State Law Library (1976).
- Tennessee State Library and Archives (unknown).
- Tennessee State University, Brown-Daniel Library (1972).
- Vanderbilt University Law Library (1976).
- Vanderbilt University Library (1884).

Sewanee: University of the South, Jesse Ball duPont Library (1873).

## TEXAS

Abilene:
- Abilene Christian University, Margaret 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, Perry-Castaneda 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 University, Walker Memorial Library (1964).
Canyon: West Texas State University, Cornett Library (1928).
College Station: Texas Agricultural and Mechanical University Library (1907).
Commerce: East Texas State University Library (1937).
Corpus Christi: Corpus Christi State University Library (1976).
Corsicana: Navarro College, Gaston T. Gooch Library (1965).
Dallas:
- Bishop College, Zale Library (1966).
- Dallas Baptist College, Vance Memorial Library (1967).
- Dallas Public Library (1900).
- Southern Methodist University, Fondren Library (1925).
- University of Texas Health Science Center-Dallas Library (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 Resource Center (1974).
- Rice University, Fondren Library (1967).
- South Texas College of Law Library (1981).
- University of Houston at Clear Lake City Library (1980).
- 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, Jernigan Library (1944).
Laredo: Laredo Junior College, Harold R. 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).
Nacogdoches: Stephen F. Austin State University, Steen Library (1965).
Plainview: Wayland Baptist University, Van Howeling Memorial Library (1963).
Richardson: University of Texas at Dallas Library (1972).
San Angelo: Angelo State University, Porter Henderson 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: Victoria College/University of Houston, 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, J. Reuben Clark 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 (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 Law School 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 Library and Archives (1968).

## VIRGINIA

Alexandria: Dept. of the Navy, General Law Library (1963).
Arlington: George Mason University School of Law Library (1981).
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, Learning Resources Center (1969).
Emory: Emory and Henry College, Kelly Library (1884).
Fairfax: George Mason University, Fenwick 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, University Library (1910).
Washington and Lee University, Wilbur C. Hall 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 University, 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).
University of Richmond, Law School Library (1982).
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, JFK Library (1966).
Ellensberg: Central Washington University Library (1962).
Everett: Everett Public Library (1914).
Olympia:
Evergreen State College, Daniel J. Evans Library (1972).
Washington State Law Library (1979).
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, Mary Gould Gallagher Law Library (1969).
U.S. Court of Appeals, 9th Circuit Library (1981).
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, Hardway Library (1972).
Charleston:
Kanawha County Public Library (1952).
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, Ruth Scarborough Library (1971).
Weirton: Mary H. Weir Public Library (1963).

## WISCONSIN

Appleton: Lawrence University, Seeley G. Mudd Library (1869).
Beloit: Beloit College, Col. Robert H. Morse Library (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 Learning Center (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 Law Library (1981).
University of Wisconsin-Madison, Memorial Library (1939).
Wisconsin State Law Library (unknown).
Milwaukee:
Alverno College Library/Media Center (1971).
Medical College of Wisconsin, Inc., Todd Wehr Library (1980).
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).
Ripon: Ripon College Library (1982).
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 Anderson Library (1963).

## WYOMING

Casper: Natrona County Public Library (1929).
Cheyenne:
Wyoming State Law Library (1977).
Wyoming State Library (unknown)–REGIONAL.
Gilette: George Amos Memorial Library (1980).
Laramie:
University of Wyoming, Coe Library (1907).
University of Wyoming 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 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

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**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

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### CALIFORNIA

••**Los Angeles**—Daniel J. Young, Director, Room 800, 11777 San Vicente Boulevard 90049, Area Code 213 Tel 209-6707, FTS 793-6707

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**San Francisco**—Betty D. Neuhart Director, Federal Building, Box 36013, 450 Golden Gate Avenue 94102, Area Code 415 Tel 556-5860, FTS 556-5868

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•**Jacksonville**—3 Independent Drive, 32202, Area Code 904 Tel 791-2796, FTS 946-2796

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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**—Steven K. Craven, Director 4106 Federal Building, P.O. Box 50026, 300 Ala Moana Boulevard 96850, Area Code 808 Tel 546-8694, FTS 8 808-546-8694

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•**Commerce Business Daily** Room 1304, 433 West Van Buren Street 60607, Area Code 312 Tel 353-2950

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**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

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|---|---|---|---|---|---|---|---|---|---|
| Publication Number | SD Catalog No. | Price | Order No. | Price | Publication Number | SD Catalog No. | Price | Order No. | Price |
| 137 | SN 003-003-02401-5 | $ 4.75 | | | 143 | SN 003-003-02397-3 | $10.00 | | |
| 138 | SN 003-003-02421-1 | $ 6.50 | | | 144 | SN 003-003-02437-6 | $ 6.50 | | |
| 139 | | | PB 82-237405 | $13.00 | 145 | SN 003-003-02405-8 | $ 6.50 | | |
| 140 | SN 003-003-02387-6 | $ 6.50 | | | 147 | SN 003-003-02418-0 | $ 7.50 | | |
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|---|---|---|---|---|---|---|---|---|---|
| 1150 | SN 003-003-02417-1 | $ 5.50 | | | 1167 | SN 003-003-02432-5 | $ 5.50 | | |
| 1156 | SN 003-003-02385-0 | $ 6.00 | | | 1170 | SN 003-003-02454-6 | $ 5.00 | | |

## SPECIAL PUBLICATIONS

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|---|---|---|---|---|---|---|---|---|---|
| 446-6 | | | PB 83-118646 | $10.00 | 624 | | | PB 82-234501 | $34.00 |
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## NBS INTERAGENCY REPORTS

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|---|---|---|---|

4. TITLE AND SUBTITLE

BUILDING TECHNOLOGY PUBLICATIONS
Supplement 7: 1982

5. AUTHOR(S)

Linda Beavers, Editor

6. PERFORMING ORGANIZATION (If joint or other than NBS, see instructions)

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**DEPARTMENT OF COMMERCE**
**WASHINGTON, D.C. 20234**

7. Contract/Grant No.

8. Type of Report & Period Covered

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Same as Item 6.

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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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