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BUILDINGS ENERGY RESEARCH: A BIBLIOGRAPHY UPDATE

R. S. Weaver, L. F. Goins, and P. M. Love

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FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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Building Thermal Envelope Systems and Materials Program

BUILDINGS ENERGY RESEARCH: A BIBLIOGRAPHY UPDATE

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CONTENTS

ACRONYMS

ANL	Argonne National Laboratory
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BECA	Building Energy Use Compilation Analysis
BEPS	Building Energy Performance Standards
BNL	Brookhaven National Laboratory
BPA	Bonneville Power Administration
BSD	Building Systems Division
BTESM	Building Thermal Envelope Systems and Materials
CACS	Commercial and Apartment Conservation Service
CFC	Chlorofluorocarbons
COP	Coefficient of performance
DOE	Department of Energy
ETFE	Ethyltetrahydrofurfurylether
GPO	Government Printing Office
GNP	Gross national product
HRCP	Hood River Conservation Project
HVAC	Heating, ventilating, and air-conditioning
LBL	Lawrence Berkeley Laboratory
MoWiTT	Mobile Window Thermal Test
NBS	National Bureau of Standards
NIST	National Institute of Standards and Technology (formerly National Bureau of Standards)
NTIS	National Technical Information Service
O/M	Operation/maintenance
ORNL	Oak Ridge National Laboratory
PNL	Pacific Northwest Laboratory
RCS	Residential Conservation Service
SERI	Solar Energy Research Institute
TECH	Tennessee Energy Conservation Housing
VOC	Volatile organic compounds

ACKNOWLEDGMENTS

The authors wish to acknowledge the many people who have been most helpful and supportive during this project. Special thanks are extended to James A. Smith of the Building Systems Division at DOE headquarters for his special interest and support; to George Courville of the Building Thermal Envelope Systems and Materials Program, ORNL, for his valuable information and advice; and to the researchers who contributed publications for this report. The authors appreciate the contribution from BEIA staff members including Sherry Daniels for data entry, Dorla Arnwine for clerical assistance, Nancy Knox for technical assistance, and Donna Stokes for the desktop publication of this report.

Many of the abstracts included in this report were obtained from the Energy Data Base, an online resource maintained by the U.S. Department of Energy's Office of Scientific and Technical Information, Oak Ridge, Tennessee.

ABSTRACT

Buildings currently account for more than one-third of the energy consumed in the United States. The Department of Energy's Building Systems Division (BSD) has sponsored a variety of research projects designed to improve energy efficiency of both new and existing buildings. A bibliography was first published in April 1983 and updated in 1985 that contained references to publications prepared for, sponsored by, or otherwise related to the scope of the BSD. This update contains 653 references to documents published from 1985 to 1989.

The list was developed from a computerized bibliographic data base maintained at Oak Ridge National Laboratory by the Health and Safety Research Division's Biomedical and Environmental Information Analysis Section. The project is managed by the Energy Division's Building Thermal Envelope Systems and Materials Program.

INTRODUCTION

OVERVIEW

The building sector accounts for approximately 27 quadrillion Btu's (quads) of energy each year, more than one-third of the total energy budget of the United States. Because energy was cheap and abundant when many of these buildings were constructed, little attention was given to energy conservation; therefore, these buildings offer considerable opportunities for application of energy-saving techniques. However, the industries related to building activities are among the country's most fragmented and are subject to large fluctuations in consumer demand, so few companies can afford a sustained commitment to long-term energy research programs. Furthermore, innovative conservation techniques may be slow to penetrate the market.

The Department of Energy (DOE) assists private industry by conducting and coordinating buildings-related energy research. DOE's Buildings Systems Division (BSD) is responsible for overseeing most of the federally sponsored research related to building structures and whole-building energy performance. Major programs include: (1) Ventilation and Controls — air infiltration and indoor air quality; (2) Envelope Systems and Materials — windows, roofing, daylighting, and insulation; and (3) Performance Calculations and Diagnostics. The mission of the BSD is to sponsor long-term research programs that would not otherwise be conducted by the private sector and to transfer this knowledge to private industry for development. The division is also responsible for field testing and validating new conservation technologies and for developing voluntary energy performance standards.

This report contains 653 references to major publications prepared by these programs and serves as an update of a bibliography that was first published in April 1983 and updated in 1985. Many of the documents listed were sponsored wholly or in part by the BSD. Other documents prepared or sponsored by other divisions or agencies are included because of their relevance to the BSD.

The list of references was generated from the Building Materials Data Base, which is maintained by the Biomedical and Environmental Analysis Section (BEIA) of the Health and Safety Research Division (HASRD) at Oak Ridge National Laboratory (ORNL) and is managed by the Building Thermal Envelope Systems and Materials (BTESM) program in the Energy Division at ORNL. The citations were gathered from a number of sources. Publication lists supplied by the BTESM program's monthly report and the Energy Division's annual publication list served as the major basis of the update. Other citations were selected from the Energy Data Base (EDB), which is maintained by DOE's Office of Scientific and Technical Information (OSTI) and the National Technical Information Service (NTIS). Letters to BTESM and DOE contacts, other national laboratories, and other institutions involved with building research resulted in additional citations.

FORMAT

The references within this bibliography are arranged alphabetically by first author, corporate affiliation, or publication description of the document. When an author is not given for a document, the corporate affiliation will appear first. If these two levels of authorship are not given, the title of the document will appear first, but the citation is integrated into the section by the alphabetical position of its publication description. Each citation contains the following data elements:

- Record number
- Author
- Corporate affiliation
- Title
- Publication description
- Publication date
- Abstract

INDEXES

The color-coded indexes are a quick guide to finding needed information. The numbers appearing after each listing in the indexes are citation numbers. The author index (pink pages) lists all authors for each citation. The corporate affiliation index (blue pages) is an alphabetical listing of the institution performing the work. The yellow pages provide a permuted index of all major words in each title. The keyword index (buff pages) is an alphabetical index of terms selected from a controlled thesaurus to characterize specific concepts.

CITATION FORM

Certain printing conventions have been established for this bibliography to express superscripts and subscripts:

1. X sub t means X_t or X subscript t.
2. For chemical compounds and elements, NaIO3 (for example) means $NaIO_3$.
3. 10(E+3) or X(E-3) (E denoting exponent) means 10^3 or X^{-3}.
4. Cubic or square dimensions of measurements are shown (for example) as 6 cu cm for 6 cubic centimeters or 3 sq km for 3 square kilometers.
5. The following prefixes have been used to indicate multiples or subdivisions of units of measurement:

a	atto	(10^{-18})	da	deca	(10^{1})
f	femto	(10^{-15})	h	hecto	(10^{2})
p	pico	(10^{-12})	k	kilo	(10^{3})
n	nano	(10^{-9})	M	mega	(10^{6})
u	micro	(10^{-6})	G	giga	(10^{9})
m	milli	(10^{-3})	T	tera	(10^{12})
c	centi	(10^{-2})	P	peta	(10^{15})
d	deci	(10^{-1})	E	exa	(10^{18})

6. The following abbreviations have been used in this publication for unit measurements:

a	acre	m	meter
A	angstroms	MeV	megaelectron volt
Bq	becquerel	min	minute
Btu	British thermal units	mpg	miles per gallon
C	Celsius	Pa	pascal
cd	candellas	pcf	pounds/cubic foot
Ci	curies	ppb	parts per billion
cu	cubic	ppm	parts per million
deg	degree	psi	pounds/square inch
F	Fahrenheit	R	thermal resistance
ft	feet	s	second
g	gram	sq	square
gal	gallon	U	shading coefficient
ha	hectare	V	volt
hr	hour	W	watt
Hz	hertz	Wh	watt-hour
in.	inch	W(e)	watt (electrical)
J	joules	W(t)	watt (thermal)
K	Kelvin	yd	yard
keV	kiloelectron volt	yr	year
l	liter		

DOCUMENT AVAILABILITY

Copies of most documents referenced in this bibliography can be obtained through either the National Technical Information Service, the Office of Scientific and Technical Information, or the Government Printing Office.

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161

Office of Scientific and Technical Information
U.S. Department of Energy
P.O. Box 62
Oak Ridge, TN 37831

Superintendent of Documents
U.S. Government Printing Office
Washington, DC 20402

Some citations consist of journal articles, papers presented at conferences, or a few chapters or sections from books. Journals can usually be located at major libraries. The author or corporate affiliation can be a good source for information concerning the availability of a publication.

SAMPLE REFERENCE

This is an example of the format for the descriptive fields used in this bibliography:

1—Record Number
(Sequential Number of Reference)
2—Author(s)
3—Corporate Affiliation
4—Document Title
5—Publication Description
6—Publication Date
7—Abstract

[1]155
[2]Domanski, P.A., [3]National Bureau of Standards, Washington, DC

[4]Recommended Procedure for Rating and Testing of Variable-Speed Air-Source Unitary Air Conditioners and Heat Pumps

[5]NBSIR-88-3781; PB-88-218227/XAB; 81 pp. [6](1988, May)

[7]A procedure is presented for testing and rating variable-speed, split residential air conditioners and heat pumps. The procedure is derived in part from existing procedures for single speed and two speed systems where these procedures could be applied, and introduces a new algorithm for representation of variable-speed unit performance in the intermediate speed operation range. Analysis and background which led to the formulation of the procedure are included as well as calculation examples for the cooling and heating mode. The procedure has been prepared for the Department of Energy for consideration in the rule making process.

BIBLIOGRAPHIC REFERENCES

1
Achenbach, P.R., and W.W. Seaton, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA

Building Industry Roundtable on Technology Transfer and Research Utilization - Proceedings

PNL-SA-12995; CONF-841258; Proceedings of an American Society of Heating, Refrigerating and Air-Conditioning/U.S. Department of Energy Roundtable, Washington, DC, December 12, 1984, 78 pp. (1985, April)

A roundtable on technology transfer and research utilization for energy conservation in buildings was conducted by the American Society of Heating, Refrigerating and Air-Conditioning Engineers as a part of the needs assessment program in research utilization of the Department of Energy. About 35 selected experts from a broad spectrum of building community organizations met in Washington, DC, to identify the constraints, discontinuities, limitations and inadequacies in the present technical information dissemination procedures and to recommend new or improved procedures and the means for carrying them out. Some of the more important recommendations of the panels reflected the need for: organized collection and reformatting of technical information for designers and builders; greater participation by DOE staff in introducing research results into handbooks and good practice guidelines; early involvement of industry representatives in planning, evaluating and monitoring research programs to stimulate interest and acceptance of output; incorporation of technology transfer objectives in the initial planning of research programs; greater DOE support for university research and for all aspects of technology transfer; preparation of more comprehensive bibliographies of technical information and computerization of the data base; and support of "proof of concept" projects to bridge the gap between laboratory research results and building practice.

2
Ackermann, R.A., Mechanical Technology, Inc., Latham, NY

Development of a Residential Free-Piston Stirling Engine Heat Pump

CONF-8804100; Research and Development on the Heat Pump for Space Conditioning Applications, Proceedings of the Second DOE/ORNL Heat Pump Conference, Washington, DC, April 17-20, 1988, 225 pp.; (8 pp.) (1988)

This paper provides a description of the free-piston Stirling Engine Heat Pump (FPSE/HP) module tested at Lennox, describes the developmental history of the FPSE/HP at Mechanical Technology Incorporated (MIT), and presents the results of the Lennox list. This work has been a collaborative effort between Massachusetts Institute of Technology (MIT), Oak Ridge National Laboratory (ORNL), Department of Energy (DOE), and the Gas Research Institute (GRI).

3
Akbari, H.A., A. Almeida, D. Connell, J.P. Harris, and M. Warren, Lawrence Berkeley Laboratory, Berkeley, CA

Assessment of Energy Management Systems for Monitoring Load-Shaping Measures in Industry

LBL-20821 (1985, December)

4
Akbari, H.A., C.C. Conner, and A.J. Usibelli, Lawrence Berkeley Laboratory, Berkeley, CA

Residential Energy Simulations in the Pacific Northwest: A Comparison of Four Widely Used Models

LBL-20221; ASHRAE Technical Paper 2985; CONF-8606125; Proceedings of the Annual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Portland, OR, June 22, 1986; (pp. 145-160); ASHRAE Transactions 92(2A):145-160 (1986)

The limitations and applicability of four different residential building energy simulation models at different levels of sophistication have been examined and compared. These models are: (1) the Standard Heat Loss Methodology (SHLM); (2) SUNDAY, a microcomputer based energy simulation model; (3) WORK4, a temperature bin method of heat loads calculation; and (4) DOE-2, a state-of-the-art public domain building energy simulation model. The comparisons were performed over a wide range of parametric conditions including changes in climate, inside temperatures, internal gains, and UA. The authors found reasonably close agreement between the WORK4 and SUNDAY models. These two models were also in reasonable agreement with DOE-2, except when modeling well-insulated homes and air infiltration changes. The SHLM model yielded substantially lower energy use estimates than the other models. In addition, the simulation results for both WORK4 and SUNDAY were collapsed into a smooth trend using a normalization procedure. This simple trend is solely defined by climatic conditions.

5

Akbari, H.A., D. Flora, and P. Le Coniac, Lawrence Berkeley Laboratory, Berkeley, CA

Using Energy Management Systems to Obtain Building Energy Data

LBL-21094; Strategic Planning for Energy Management 6(1):43-62 (1986, March)

EMS-derived data may offer important advantages, in terms of cost and effort versus data quality, as compared with conventional approaches now being used to analyze end-use performance in large buildings. Of course, using EMS's for performance monitoring will not be equally promising in all commercial buildings nor for all data needs. There must be a computerized energy management system already in place, with appropriate sensing, data storage, and communication capabilities. However, these systems are already becoming standard equipment, especially in buildings larger than 100,000 square feet. It is possible to take advantage of the data available from even a simple EMS to determine some operating characteristics of a commercial building, especially to understand the way the electricity is used. Hourly EMS data help to indicate the weather dependency of the energy use in the building and can be used as constraint in load profile estimations where they are invaluable in establishing an accurate end-use breakdown.

6

Akbari, H.A., M. Warren, J.P. Harris, C.B. Smith, T. Davis, and M. Keneipp, Lawrence Berkeley Laboratory, Berkeley, CA

Energy Management Systems in Large Commercial Buildings: Monitoring and Control Capabilities

LBL-21041; CONF-8604109; Productivity Through Energy Innovation; Proceedings of the Pacific Gas and Electric (PG and E) Energy Exposition, Oakland, CA, April 29, 1986. Pergamon Books, Inc., Elmsford, NY; (pp. 106-122) (1986, March)

The number of existing Energy Management Systems (EMS's) in both retrofitted and new commercial buildings is significant and growing. To assess benefits of this technology to building owners, occupants, operators, and utilities, the major characteristics of EMS's currently available on the market have been reviewed in terms of their hardware, software, and intra- and inter-system communications capabilities. Examples of data collection by two types of EMS's have been given to show how the gathered information could be utilized by both building operators and utilities to document energy consumption and peak electricity demand in buildings. A brief discussion of the commonly offered load management software is presented. Finally, communications protocols that allow access to the data resident in the EMS are discussed.

7

Albrand, P., I. Turiel, R.L. Ritschard, and D.J. Wilson, Lawrence Berkeley Laboratory, Berkeley, CA

Low Rise Multi-Family Housing: A Preliminary Survey of Building Characteristics and Prototype Development

LBL-20229; 32 pp. (1985, November)

In order to develop a prototypical building with which computer simulations on energy use will be performed and to identify several major research issues, we sampled a group of U.S. builders to gather data on construction characteristics and space conditioning systems in new multi-family buildings. We obtained useful data on insulation levels, building materials, window types, and space conditioning equipment. Where data are available, we make comparisons with other studies.

8
American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., New York, NY; Building Thermal Envelope Coordinating Council, Washington, DC

Thermal Performance of the Exterior Envelopes of Buildings - III

ASHRAE-SP-49; CONF-851202; Thermal Performance of the Exterior Envelopes of Buildings - III, Proceedings of the DOE-ORNL-ASHRAE-BTECC Conference, Clearwater Beach, FL, December 2, 1985, 1421 pp. (1986)

This report is a collection of the proceedings of the ASHRAE/DOE/BTECC conference of December 2-5, 1985. General topics include: in-situ measurement of energy use; air infiltration; thermal analysis of building envelopes; retrofitting techniques; design of buildings in hot cold climates; and economics.

9
Andrews, J.W., B.H. Fleck, R.F. Krajewski, and R.J. McDonald, Brookhaven National Laboratory, Upton, NY

Thermal Distribution and Utilization: An Interim Progress Report

BNL-51871; 60 pp. (1985, February)

This is the first of a series of reports describing technical progress of a research program entitled: "Thermal Distribution and Utilization." The subject of the research is the building systems used to distribute heat and cooling from central equipment to building spaces and the control of these systems to provide thermal comfort while minimizing the expenditures of primary energy. Report describes 1985 plan of work and technical progress reports through January 1985. An introductory section outlines the energy impact projections upon which the program is based.

10
Andrews, J.W., R.J. McDonald, R.F. Krajewski, L.M. Woodworth, and J.E. Batey, Brookhaven National Laboratory, Upton, NY

Triage of Oil and Gas Retrofits for Residential/Light Commercial Heating Systems

BNL-38090; 78 pp. (1986, May)

The objective of this report was to assemble all known information about oil and gas retrofits for residential/light-commercial heating system applications and classify them into five distinct groups. It is meant to be used as a guideline for the U.S. DOE to use in considering support of retrofit programs that are being conducted on the city and state levels. Those five classifications are: (1) Retrofits with proven savings potential; (2) Retrofits with potential savings requiring additional verification; (3) Retrofits with unknown savings potential requiring engineering analysis; (4) Retrofits for research programs; and (5) Retrofits with no significant savings. A technical description for each option follows which briefly describes what the retrofit does, how it works, limitations on application, and general procedures for proper installation or operation. A short discussion of the advantages and disadvantages is included to help classify, analyze, and prioritize the retrofits. Where applicable, project savings were estimated as well as a range for the installed costs of each retrofit.

11
Apte, M.G., and G.W. Traynor, Lawrence Berkeley Laboratory, Berkeley, CA

Comparison of Pollutant Emission Rates From Unvented Kerosene and Gas Space Heaters

LBL-21571; 27 pp.; CONF-860446; IAG '86: Managing Indoor Air For Health and Energy Conservation, Proceedings of a Conference, Atlanta, GA, April 20, 1986 (1986, May)

Pollutant emission rates of all five types of unvented space heaters were compared and pollutant emission rates for carbon dioxide (CO2), carbon monoxide (CO), nitric oxide (NO), nitrogen dioxide (NO2), formaldehyde, and submicron suspended particles were measured. Special emphasis is placed on CO2 and NO2 emissions. Pollutant measurements were made in a 27 cu m environmental chamber and emission rates were calculated using a mass-balance model. Emission rates for propane and natural gas space heaters were similar. The effects of various operation parameters such as the wick height for kerosene heaters and the air shutter adjustment for gas heaters are discussed.

12
Arasteh, D., et al., Lawrence Berkeley Laboratory, Berkeley, CA

WINDOW: A Computer Program for Calculating U-Values and Shading Coefficients of Windows

LBL-20212 (1986, July)

13
Arasteh, D., J. Hartmann, and M. Rubin, Lawrence Berkeley Laboratory, Berkeley, CA

Experimental Verification of a Model of Heat Transfer Through Windows

LBL-21576; 10 pp.; CONF-870101; Proceedings of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers Meeting, New York, NY, January 18-21, 1987; ASHRAE Transactions 93(1):1425 (1986, December)

A procedure has been developed for calculating the one-dimensional heat flux through complex window systems. A computer program embodying this procedure (WINDOW 2.0) is available to the public. The window may consist of multiple glass or plastic layers, separated by gas-filled spaces. Gases other than air may fill the space between solid layers, and the layers may have low-emissivity coatings. Measurements from five different manufacturers and researchers of the overall thermal conductance of various window systems confirm the validity of this model for a range of temperatures and layer spacings less than 3 cm (1.2 in.). A list of U-values and shading coefficients is given for a representative group of windows.

14
Arasteh, D., R. Johnson, and S. Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

The Effects of Skylight Parameters on Daylighting Energy Savings

LBL-17456; 21 pp. (1985, May)

Skylight parameters that affect lighting, cooling, heating, fan, and total energy use in office buildings are examined using the state-of-the-art building energy analysis computer code, DOE-2.1B. The lighting effects of skylight spatial distribution, skylight area, skylight visible transmission, well factor, illumination setpoint, interior partitions, ceiling height, and glazing characteristics are discussed. This study serves as the foundation for the creation of a DOE-2.1B data base and design tools for estimating daylighting energy savings from skylights.

15
Arasteh, D., R. Johnson, S. Selkowitz, and D. Connell, Lawrence Berkeley Laboratory, Berkeley, CA

Cooling Energy and Cost Savings With Daylighting in a Hot and Humid Climate

LBL-19734; 10 pp.; CONF-8509126; Hot Humid Climate, Proceedings of a Conference, College Station, TX, September 24-26, 1985 (1985, July)

Fenestration performance in nonresidential buildings in hot climates is often a large cooling load liability. Proper fenestration design and the use of daylight-responsive dimming controls on electric lights can, in addition to drastically reducing lighting energy, lower cooling loads, peak electrical demand, operating costs, chiller sizes, and first costs. Using the building energy simulation programs DOE-2.1B and DOE-2.1C, lighting energy savings from daylighting is discussed. The effects of fenestration parameters on cooling loads, total energy use, peak demand, chiller sizes, and initial and operating costs are also reviewed. The impact of daylighting, as compared to electric lighting, on cooling requirements is discussed as a function of glazing characteristics, location, and shading systems.

16

Arasteh, D., R. Johnson, S. Selkowitz, and R. Sullivan, Lawrence Berkeley Laboratory, Berkeley, CA

Energy Performance and Savings Potentials with Skylights

LBL-17457; 29 pp.; CONF-850123; Proceedings of the Semiannual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Chicago, IL, January, 27-30, 1985; ASHRAE Transactions 91(1) (1984, December)

This study systematically explores the energy effects of skylight systems in a prototypical office building module and examines the savings from daylighting. For specific climates, roof/skylight characteristics are identified that minimize total energy or peak electrical demand. Simplified techniques for energy performance calculation are also presented based on a multiple regression analysis of our data base so that one may easily evaluate daylighting's effects on total and component energy loads and electrical peaks. This provides additional insights into the influence of skylight parameters on energy consumption and electrical peaks. We use the DOE-2.1B energy analysis program with newly incorporated daylighting algorithms to determine hourly, monthly, and annual impacts of daylighting strategies on electrical lighting consumption, cooling, heating, fan power, peak electrical demands, and total energy use. A data base of more than 2000 parametric simulations for 14 U.S. climates has been generated. Parameters varied include skylight-to-roof ration, shading coefficient, visible transmittance, skylight-well light loss, electric-lighting power density, roof-heat transfer coefficient, and electric lighting control type.

17

Arasteh, D., and S. Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

Prospects for Highly Insulating Window Systems

LBL-19492; 16 pp.; CONF-8505167; Conservation in Buildings: Northwest Perspective, Proceedings of a Conference, Butte, MT, May 19-22, 1985 (1985, April)

Windows and other fenestration systems are often considered the weakest links in energy-efficient residences. This opinion is reinforced by building standards, audit guidelines, and standard window performance evaluation techniques geared toward sizing building HVAC equipment. In this paper we show that it should be possible to design highly insulating windows (U less than 0.12 Btu/hr/sq ft/F) with high solar transmittance (SC greater than 0.6). If we then view annual window performance from the basic perspective of control of energy flows, we conclude that it should thus be possible to develop a new generation of "super windows" that will outperform the best insulated wall or roof for any orientation even in a northern climate. We review several techniques approaches that suggest how such a window system might be designed and built. These include multiglazed windows having one or more low-emittance coatings and gas-filled or evacuated cavities. Another approach uses a layer of transparent silica aerogel, a microporous material having a conductivity in air of about R7 per inch. We conclude by presenting data on annual energy performance in a cold climate for a range of "super windows".

18

Arthur D. Little, Inc., Cambridge, MA

Status of Free-Piston Stirling Engine-Driven Heat Pumps: Development, Issues, and Options

ORNL/Sub-84/00205/1; 201 pp. (1985, April)

This report summarizes the results of a program to review the recent experience with free piston Stirling engine (FPSE) driven heat pump systems and to identify key technical and cost issues which should be the focus of the future program efforts. The effort emphasizes experience with the programs undertaken by General Electric Company (inertial compressor concept) and Mechanical Technology, Inc. (hydraulically coupled system) since they have received the major funding by the Department of Energy and others since the late 1970's. Issues addressed by the study include the status and prospects of FPSEs as heat pump drives, design and operational characteristics which might limit reliability and life, unique factors such as gas spring losses, influencing the efficiency of FPSE, and the cost constraints on the system to be economically competitive with conventional equipment and other heat actuated heat pump options. Special attention was given to the impacts of unlubricated seal and bearing options on system life, reliability, and cost.

19
Association of Collegiate Schools of Architecture, Washington, DC

Design and Energy: 1987 Student Design Competition Program Book

Annual Publication; 16 pp. (1987)

This program document for a national architectural student design competition addresses the importance of energy conscious design. The stated challenge was to design a new building for a School of Architecture on a university campus. Design problems, evaluation, competition guidelines and project summary information is included. The program administered by the Association of Collegiate Schools of Architecture was sponsored by the U.S. Department of Energy, Oak Ridge National Laboratory, The Brick Institute of America, and the Canadian Ministry of Energy.

20
Association of Collegiate Schools of Architecture, Washington, DC

Design and Energy: 1985 Student Design Competition Summary Book

Annual Publication; 40 pp. (1985)

A brief description and drawings of the winning entries of a national architectural student design competition addressing the importance of energy conscious design is presented. The stated challenge was to design "New Housing" for a downtown neighborhood. The program was administered by the Association of Collegiate Schools of Architecture and sponsored by the U.S. Department of Energy and the Brick Institute of America. An overall summary is presented of America the program and the range of submission grouped by problem types and general climatic region.

21
Association of Collegiate Schools of Architecture, Washington, DC

Design and Energy: 1987 Student Design Competition Summary Book

Annual Publication; 40 pp. (1987)

A jury of nationally recognized architects convenes each year to evaluate student design proposals submitted for a national design competition. This publication outlines and highlights the resulting projects addressing the design, "A New Building for the School of Architecture on a University Campus." The competition, administered by the Association of Collegiate Schools of Architecture, addresses the importance of energy conscious buildings.

22
Bales, E., New Jersey Institute of Technology, Newark, NJ

ASTM/DOE Hot Box Round Robin

ORNL/Sub-84/9733/2 (1988)

This report presents the data analysis from twenty-one laboratories that completed a series of tests on 4-in. thick specimens of polystyrene in either guarded or calibrated hot boxes (ASTM C-236). The data analyses resulted in recommended precision and bias statements for the two ASTM Standard Test methods.

23
Balistocky, S., A.A. Bohn, J.A. Heidell, P.L. Hendrickson, A.D. Lee, R.G. Pratt, and Z.T. Taylor, Pacific Northwest Laboratory, Richland, WA

Impacts of Alternative Residential Energy Standards - Rural Housing Amendments Study: Phase I - Executive Summary

PNL-5694-1(Exec. Summ.); 34 pp. (1985, November)

The results of a preliminary study on the impacts of several national energy conservation standards that apply to manufactured housing (mobile homes) and conventional site-built housing are presented. The housing market and how these standards affect the overall energy economics of these two housing types are briefly discussed.

24
Balistocky, S., A.A. Bohn, J.A. Heidell, P.L. Hendrickson, A.D. Lee, R.G. Pratt, and Z.T. Taylor, Pacific Northwest Laboratory, Richland, WA

Impacts of Alternative Residential Energy Standards - Rural Housing Amendments Study: Phase I

PNL-5694-1; 129 pp. (1985, November)

This report has examined the role of manufactured housing in the housing market, the energy impacts of three manufactured housing standards and three site-built standards in 13 cities, and the economic impacts of those standards in 6 cities. The three standards applied to manufactured housing are the HUD Title VI standard (Manufactured Housing Construction and Safety Standards, or MHCSS), the Hud Title II-E standard, and the existing FmHA Title V standard. Those applied to site-built homes are the HUD Minimum Property Standards (MPS), the ASHRAE 90A-80 standard, and the FmHA Title V standard. Based on energy consumption alone, these analyses show that the FmHA Title V standard is the most stringent standard for both housing types (a single-section manufactured home and a single-story detached "ranch house"). The HUD Title VI standard is the least stringent for manufactured homes, while the HUD Minimum Property Standards are the least stringent for site-built homes. Cost-effectiveness comparisons required by the Act were made for the two prototypical homes. Results of this preliminary economic analysis indicate that none of the site-built standards reflect minimum life-cycle cost as a basic criterion of their development. For manufactured homes, both the FmHA standard and the HUD Title II-E standard reduce life-cycle cost and effect positive first-year cash flows in all cities analyzed when electric resistance heating is assumed. When natural gas heating is used, both standards pass the life-cycle cost test in all cities, but the FmHA standard fails the cash flow test in all but one city. However, in the worst case, net monthly expenditures in the first year are increased by less than $9.

25
Batey, J.E., and R.J. McDonald, Brookhaven National Laboratory, Upton, NY

Summary of Proceedings: Oil Heat Technology Conference and Workshop

BNL-52018; 54 pp.; CONF-8509328; Proceedings of the Oil Heat Technology Conference and Workshop, Upton, NY, September 23, 1985 (1986, June)

This report summarizes the proceedings of the 1985 Oil Heat Technology Conference and Workshop conducted at Brookhaven National Laboratory (BNL) on September 23-24, 1985. The meeting was sponsored by the United States Department of Energy, Office of Building and Community Systems, as a technology transfer activity related to the ongoing Combustion Equipment-Space Conditioning Technology Program at BNL. The meeting was structured into three separate parts. The first included technical presentations by researchers and developers of innovative equipment and systems in order to update the meeting attendees as to current research results and developments. The second was a panel discussion to introduce issues related to high efficiency heating technology applications, industry problems, and future directions toward improving oil heat technology. The third part consisted of dividing the attendees into four working groups, to conduct workshop sessions. These groups were formed in order to discuss the issues in more depth and to come up with suggestions and recommendations for future research and development activities leading to advances in the state-of-the-art in efficient oil heating technology.

26
Bauman, F., W. Place, J. Thornton, and T.C. Howard, Lawrence Berkeley Laboratory, Berkeley, CA

Integrating Window Pyranometer for Beam Daylighting Measurements in Scale-Model Buildings

LBL-19494; 18 pp.; CONF-860106; Proceedings of the Semiannual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, San Francisco, CA, January 19, 1986 (1985, December)

An experimental device has been developed to measure the total amount of solar radiation transmitted through glazed apertures in scale-model buildings. The device, an integrating window pyranometer (IWP), has two distinguishing characteristics: (1) it provides a measure of transmitted solar radiation integrated over a representative portion of the model glazing, accounting for nonuniform radiation distributions; and (2) it is spectrally independent. In applications to scale-model daylighting experiments, the IWP, together with photometric sensors mounted in the model, allows the direct measurement of the fraction of transmitted solar gains reaching the work plane as useful illumination, a convenient measure of the daylighting system performances.

27
Baxter, V.D., Oak Ridge National Laboratory, Oak Ridge, TN

Data Acquisition and Testing at the Tennessee Energy Conservation Housing (TECH) Complex

(1986, March)

28
Baxter, V.D., Oak Ridge National Laboratory, Oak Ridge, TN

Vapor Compression Heat Pump Systems Field Tests at the TECH Complex

AIP Conference Proceedings 135(1):323-346; CONF-850414; Proceedings of an American Physical Society General Meeting, Washington, DC, April 25, 1985 (1985)

The Tennessee Energy Conservation in Housing (TECH) complex has been utilized since 1977 as a field test site for several novel and conventional heat pump systems for space conditioning and water heating. Systems tested include: the Annual Cycle Energy System (ACES), solar assisted heat pumps (SAHP) both parallel and series, two conventional air-to-air heat pumps, an air-to-air heat pump with desuperheater water heater, and horizontal coil and multiple shallow vertical coil ground-coupled heat pumps (GCHP). A direct comparison of the measured annual performance of the test systems was not possible. However, a cursory examination revealed that the ACES had the best performance, however, its high cost makes it unlikely that it will achieve wide-spread use. Costs for the SAHP systems are similar to those of the ACES, but their performance is not as good. Integration of water heating and space conditioning functions with a desuperheater yielded significant efficiency improvement at modest cost. The GCHP systems performed much better for heating than for cooling and may well be the most efficient alternative for residences in cold climates.

29
Baxter, V.D., Oak Ridge National Laboratory, Oak Ridge, TN

ORNL Air-Source Heat Pump Field

Experiments

CONF-841231; Research and Development on Heat Pumps for Space Conditioning Applications, Proceedings of the DOE/ORNL Heat Pump Conference, Washington, DC, December 10, 1984; (pp. 39-43) (1985, August)

Prior to 1981, heat pump performance ratings published by the Air-Conditioning and Refrigeration Institute (ARI) and others included only steady-state performance at heating (at -8.3 C and 8.3 C) and cooling (at 35 C). While such ratings give an indication of relative efficiencies of different units, they are not accurate indicators of seasonal performance since a heat pump's seasonal performance is degraded from steady-state levels. The objective of the air-source heat pump tests at ORNL is and has been to develop a data base of field-measured heat pump performance. Information obtained includes: seasonal performance factors; magnitudes of frosting, defrosting, and cycling losses; and an assessment of the effect of a desuperheater water heater on system performance.

30

Baxter, V.D., and V.C. Mei, Oak Ridge National Laboratory, Oak Ridge, TN

Overview of Ground Coupled Heat Pump Research and Technology Transfer Activities

CONF-8804100; Research and Development on the Heat Pump for Space Conditioning Applications, Proceedings of the Second DOE/ORNL Heat Pump Conference, Washington, DC, April 17-20, 1988, 225 pp.; (9 pp.) (1988)

Highlights of DOE-sponsored ground coupled heat pump (GCHP) research at Oak Ridge National Laboratory (ORNL) are presented. ORNL, in cooperation with Niagara Mohawk Power Company, Climate Master, Inc., and Brookhaven National Laboratory, developed and demonstrated an advanced GCHP design concept with shorter ground coils that can reduce installed costs for northern climates. In these areas it can also enhance the competitiveness of GCHP systems versus air-source heat pumps by lowering their payback from 6-7 years to 3-5 years. Ground coil heat exchanger models (based primarily on first principles) have been developed and used by others to generate less conservative ground coil sizing methods. An aggressive technology transfer initiative was undertaken to publicize results of this research and make it available to the industry.

31

Baxter, V.D., and J.C. Moyers, Oak Ridge National Laboratory, Oak Ridge, TN

Field Measured Cycling - Frosting and Defrosting Losses of a High Efficiency Air Source Heat Pump

CONF-850606; Proceedings of the Semiannual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Honolulu, HI, June 23-26, 1985; ASHRAE Transactions 91(2B):537-554 (1985)

An air-to-air heat pump was installed in an unoccupied single-family residence and operated in a two-year test to characterize dynamic losses in capacity and efficiency due to cycling, frosting, and defrosting. During the heating season, defrosting losses were responsible for 10.2% of the total energy consumption (excluding supplemental electric resistance heating), frosting losses for 3.7%, start-up transient losses for 8.5%, and off-cycle parasitics for 3.3%. The heating cyclic degradation factor, C sub d, was estimated to be 0.26. Cooling mode steady-state performance of the heat pump was degraded from the manufacturer's ratings due most likely to a small refrigerant leak resulting in a slight charge deficiency. However, using the site measured performance as the steady-state base, it was found that start-up transient losses accounted for 2.8% of the total energy use and off-cycle parasitics for 4.4%. The cooling C sub d was estimated to be 0.11 on this basis.

32

Baxter, V.D., and J.C. Moyers, Oak Ridge National Laboratory, Oak Ridge, TN

Air-Source Heat Pump: Field Measurement

of Cycling, Frosting, and Defrosting Losses, 1981-1983

ORNL/CON-150; 113 pp. (1984, November)

An air-to-air heat pump was installed in a single-family residence near Knoxville, Tennessee, and was operated in a multiyear test to permit characterization of dynamic losses in capacity and efficiency due to cycling, frosting, and defrosting. The residence and heat pump were extensively instrumented, and a state-of-the-art data acquisition system logged data for each of the several system operating modes (start-up transient heating and cooling, normal-mode heating and cooling, and defrost with recovery) throughout the testing period. For the test heating seasons, defrosting was responsible for 10.1%, losses due to frosting for 3.6%, on-off cycling losses for 8.4%, and off-cycle parasitic for 4.3% of the total energy consumption (exclusive of supplemental electric resistance heater energy use as required by second-stage thermostat demand). An overall heating seasonal performance factor of 1.96 was realized, and the value of the cyclic degradation factor, C sub d, in heating was found to be 0.24. Both output loss per cycle and input energy increase per cycle were directly related to off-time per cycle, increasing strongly with off-times up to approximately 20 min and at a much lower rate thereafter. Defrost time per defrost cycle and the associated energy use penalty varied directly with frosting potential; the effect of ambient temperature on defrost time is not clear, and additional investigation is warranted. Use of a desuperheater for domestic water heating reduced the heat pump's space heating capacity but had no measurable effect on dynamic loss levels. The steady-state cooling capacity and coefficient of performance (COP) of the heat pump were degraded from the manufacturer's ratings and those which were measured in initial steady-state tests, precluding definitive evaluation of dynamic losses during cooling operation. The cyclic degradation factor, C sub d, in cooling was estimated to be between 0.20 and 0.25.

33
Beale, W.T., and G. Chen, Oak Ridge National Laboratory, Oak Ridge, TN; Sunpower, Inc., Athens, OH

Preliminary Assessment of a Magnetically Coupled Free-Piston Stirling Engine Heat Pump Compressor

CONF-8804100; Research and Development on the Heat Pump for Space Conditioning Applications, Proceedings of the Second DOE/ORNL Heat Pump Conference, Washington, DC, April 17-20, 1988, 225 pp.; (6 pp.) (1988)

The potential advantages of direct magnetic coupling of a free-piston stirling engine with a vapor compressor are being investigated, experimentally. Results include no problems with dynamics, mechanical arrangements, efficiency, or deterioration, but problems with size and cost remain.

34
Beck, J.V., and M.A. Karnitz, Oak Ridge National Laboratory, Oak Ridge, TN

Parameter Estimation Study of Heat Losses from Underground Steam Pipelines

ORNL/TM-9928; 48 pp. (1986, June)

Central heating plants distribute energy by sending steam or hot water through buried pipelines. Some heat losses occur during operation of these pipelines. The values of such losses are needed for several reasons, such as determining if maintenance needs to be done on a section of pipeline. This report presents a study of procedures for estimating heat losses based on underground temperature measurements. Subsurface temperature measurements obtained at Oak Ridge National Laboratory were used to estimate pipe heat loss and pipe depth. The data were analyzed in several ways. In one way, parameters were estimated at each axial position of the pipe. In another, the data were used to obtain a single set of parameters in a sequential manner that gives insight into the effect of including measurements at each location. A method was also suggested which can aid in determining if the soil thermal conductivity can be simultaneously estimated with the heat loss per foot.

35
Benton, C., B. Erwine, M. Warren, and S. Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

Field Measurements of Light Shelf Performance in a Major Office Installation

LBL-21411; 10 pp.; CONF-860655; Proceedings of the 1986 Annual American Solar Energy Society Meeting and the Eleventh National Passive Solar Conference, Boulder, CO, June 8-14, 1986 (1986, July)

Electric lighting is a major component of electrical energy use in large commercial buildings and has additional significant impact on the cooling energy requirements. This paper evaluates the monitored performance of such an integrated lighting scheme in a recently completed 600,000 sq ft office structure located in the San Francisco Bay Area. Decentralized data acquisition systems monitored 62 different locations in the building between May 1985 and January 1986, recording average illuminance levels and corresponding ambient lighting power usage across the north and south building sections. A graphic summary of data compares the performance of effectiveness of the building's lightshelf system for north and south orientations. One counterintuitive conclusion of the study is that the "dimmer" north side light shelf scheme exhibits a higher potential (69% reduction from full power) for electric light reduction than the "brighter" south side scheme (56% reduction).

36
Benton, C., M. Warren, S. Selkowitz, R. Verderber, J. McBride, O. Morse, and J.E. Jewell, Lawrence Berkeley Laboratory, Berkeley, CA; Pacific Gas and Electric Company, San Francisco, CA

Field Evaluation of Daylighting System Performance

LBL-20118; 11 pp.; CONF-860901; Advancing Building Technology, Proceedings of the Tenth CIB Congress, Washington, DC, September 21, 1986 (1986, July)

This paper describes the performance of a 56,000 sq m office building, emphasizing the use of daylighting for ambient illumination. Natural light serves 3000 employees in open-plan offices through the building's five floors. The architectural scheme includes ceilings that slope from 4.25 m (perimeter) to 2.75 m (center), 3.5 m-deep light shelves at the exterior walls, and a central atrium providing light to interior spaces. An electric lighting system supplements available daylight, when necessary, using fluorescent fixtures with continuously dimming ballasts controlled by photocells. Monitoring during a one-year period has confirmed that the daylighting elements of the building provide ambient illumination in a pattern predicted by the design studies. Between 8 a.m. and 6 p.m. on an average summer day, the building's southern half can potentially maintain the target illuminate of 350 lux with an electric lighting load of 44% full power. The northern half of the building would require less electrical lighting at 31% of full power. However, actual measured electrical power consumption for ambient lighting is higher at 75% of full power for the south side and 50% of full power for the north side. The day-lighting component of interior illuminance peaks at seven times the target level for ambient light. Proper design and tuning of the electric light control system was determined essential for the realization of projected savings in electric power consumption.

37
Berman, S., Lawrence Berkeley Laboratory, Berkeley, CA

Lighting Research Program

LBL-19277; CONF-850301; Proceedings of the Twelfth Annual Energy Technology Conference and Exposition, Washington, DC, March 25, 1985; Energy Technology 12:918-927 (1985, August)

Energy-efficient lighting could reduce 50% of the electrical energy consumed by lighting (about 12% of total national electrical energy sales), which would yield a savings of 220 billion kW/hr of electricity. The DOE Lighting Program carried out at Lawrence Berkeley Laboratory helps manufacturers, designers, and users achieve a more efficient lighting economy. The program is a unique partnership between a national laboratory/university complex and industry. The author describes the scope of the program under its three major categories of engineering science, electromagnetic compatibility, and impacts on human health and productivity.

38

Berman, S., D.L. Jewett, L.R. Bingham, R.M. Nahass, F. Perry, and G. Fein, Lawrence Berkeley Laboratory, Berkeley, CA; University of California, San Francisco, CA

Pupillary Size Differences Under Incandescent and High Pressure Sodium Lamps

LBL-21476; 25 pp.; CONF-8608179; Proceedings of the 1986 Annual Illuminating Engineering Society Conference, Boston, MA, August 17-21, 1986 (1986, April)

Eight healthy young adult subjects produced significantly larger steady state pupil areas, as measured by infra-red pupillometry, when exposed to indirect lighting from high frequency high pressure sodium lamps compared to photopically matched levels of indirect incandescent lamps at three levels of luminance: 30, 60 and 90 cd/sq m. Three additional intensities were studied, which were not matched photopically between lamps. Analysis of all data showed that a scotopic spectral distribution accounted for pupil size better than either a photopic spectrum or an Alpern-Campbell pupillary response spectrum. Because pupil size can affect visual functioning, these results suggest that control of pupil size should be considered in lighting design and that the scotopic spectral output from lamps should be important in determining the effectiveness of a lighting environment.

39

Berntsson, T., and H. Schnitzer, Chalmers University of Technology, Goeteborg, Sweden; Technische University, Graz, Austria

Study of Working Fluid Mixtures and High Temperature Working Fluids for Compressor Driven Systems

Final Report (IEA Annex VI) (1985, September)

40

Berntsson, T., and H. Schnitzer, Chalmers University of Technology, Goeteborg, Sweden; Technische University, Graz, Austria

Study of Working Fluid Mixtures and High Temperature Working Fluids for Compressor Driven Systems: Final Report, Part A

NP-6901084; 126 pp. (1986, September)

High temperature working fluids and nonazeotropic mixtures in compressor driven heat pumps are the topics of study. Heat transfer aspects of mixtures and recent developments in high temperature heat pumps are briefly discussed. Computer programs for the study are described, and some economics of compression heat pumps are considered.

41

Berntsson, T., and H. Schnitzer, Chalmers University of Technology, Goeteborg, Sweden; Technische University, Graz, Austria

Study of Working Fluid Mixtures and High Temperature Working Fluids for Compressor Driven Systems: Final Report, Part B

NP-7900317; 159 pp. (1986, September)

The objectives of this study are to gather theoretical and experimental information for heat pump systems operating with new working fluids or mixtures with special emphasis on nonazeotropic mixtures, and to evaluate their potential in comparison with other heat pump systems.

42

Berry, L.G., J. Bledsoe, T.A. Vineyard, and D.L. White, Oak Ridge National Laboratory, Oak Ridge, TN

Evaluation of Gas Heating System Retrofit Pilot Programs in Kentucky and Minnesota

ORNL/CON-229; 67 pp. (1987, March)

Gas-heating-system retrofit pilot programs for low-income households were conducted in Minnesota and Kentucky in 1985. These programs were aimed at improving the cost effectiveness of low-income residential conservation programs by demonstrating and encouraging the transfer of gas heating system retrofit technologies into existing weatherization assistance programs. To determine the fuel savings and cost effectiveness of the four gas-heating-system retrofit types, an experimental design with random assignment to treatment and control groups was implemented. The Princeton Scorekeeping Method (PRISM) was used to measure fuel savings by comparing treatment and control group consumption for the year before and the year after the retrofits were installed. Cost effectiveness was estimated by calculating the net present value of the retrofits.

43

Berry, L.G., M.S. Hubbard, and D.L. White, Oak Ridge National Laboratory, Oak Ridge, TN

A Review of Financial Incentive, Low-Income, Elderly and Multi-Family Residential Conservation Programs

ORNL/CON-206; 106 pp. (1986, September)

Thirty-nine utility-sponsored residential conservation programs for four types of markets are described in this report. The program types considered are: (1) financial incentive programs for the general residential market, (2) programs for low-income households, (3) programs for the elderly, and (4) programs for the multifamily market. Each program description contains information on incentive terms, eligibility, conservation measures, program history, design and marketing, and the utility/agency motivation for operating the program. Two methods were used to select the programs to be described. First, nominations of successful programs of each type were solicited from experts on residential energy conservation. Second, managers of the programs on this initial list were asked to describe their programs and to suggest other successful programs that should be included in the sample.

44

Berry, L.G., M. Schweitzer, and E. Freeman, Oak Ridge National Laboratory, Oak Ridge, TN

Marketing and Design of Residential Energy Conservation Programs for the Elderly

ORNL/CON-246; 220 pp. (1988, February)

This report describes barriers to energy conservation by the elderly. Because of these barriers, they have a greater need for programs that assist with the installation of energy-efficiency improvements. In response to this need, a number of specialized programs are operated for the elderly. Descriptions of 39 energy conservation programs for the elderly are contained. Telephone interviews were conducted with the managers of these programs to identify marketing techniques and organizational structures. Interagency networking, presentations and referrals are the most common methods of recruiting clients. Other marketing techniques in order of the frequency of use are: direct mail, bill inserts, television, radio, printed materials, and telemarketing. Many managers consider word-of-mouth advertising from satisfied clients the most effective form of marketing. Intragency networking and support (financial, structural and in-kind) can offer real advantages in the operation of conservation programs for the elderly.

45

Berry, L.G., and T.A. Vineyard, Oak Ridge National Laboratory, Oak Ridge, TN

Evaluation Plan for State Gas Heating System Retrofit Pilot Programs

ORNL/CON-171; 94 pp. (1985, March)

This report presents a detailed plan for the evaluation of state gas heating system retrofit pilot programs. The major goals of the evaluation procedures are to document the fuel savings and cost effectiveness of: (1) the programs implemented by the states and (2) the four retrofit types installed. The major tasks involved in the evaluation include identification of program-eligible households, screening for data quality, assignment of eligible households to treatment or control groups, assembling cost data, collecting pre- and post-retrofit consumption data, obtaining pre- and post-retrofit weather data, checking for data quality, and analyzing the data. Data analysis relies on the calculation of weather-adjusted normalized annual consumption (NAC) figures for pre- and post-retrofit years for treatment and control groups. The differences between the treatment and control groups' NACs for the pre- and post-retrofit years are the measure of the program's impact. Cost effectiveness analysis will combine the NAC results with cost data and with a variety of assumptions concerning future fuel prices, retrofit lifetimes, and discount rates to produce benefit/cost indicators.

46
Bertram, K.M., Argonne National Laboratory, Argonne, IL

A U.S. Department of Energy Revolving Loan Fund: Analysis of Potential Applications Supporting Integrated Community Energy Systems

ANL-CNSV-TM-164; 41 pp. (1985, June)

This study identifies and evaluates several potential applications for a U.S. Department of Energy (DOE) Revolving Loan Fund (RLF) to promote district heating and cooling (DHC) and grid-connected integrated community energy systems (GC-ICES). Project loans from the $10-million RLF now under consideration would tentatively have a maximum size of $300,000 and would be repayable over three to five years on a monthly "mortgage payment" basis at below-market interest rates. Monthly payments on outstanding loans would generate constant inflows of cash, which, under effective cash-management practices, could keep government costs of the RLF to a minimum. Public-sector and nonprofit organizations would be eligible to use the RLF. Also eligible would be private-sector firms developing projects in conjunction with public or nonprofit organizations, as well as corporate users of DHC systems and GC-ICES. On the basis of this research, it is concluded that several effective uses would be immediately available for the revolving loan fund, if and when it is implemented.

47
Birdsall, B.E., Lawrence Berkeley Laboratory, Berkeley, CA

A Comparison of DOE-2.1C Prediction with Thermal Mass Test Cell Measurements

LBL-18981; 35 pp. (1985, January)

This report describes a Comparison of DOE-2.1C Predictions with Thermal Mass Test Cell Measurements performed by the Building Energy Simulation Group of the Applied Science Division (ASD) at Lawrence Berkeley Laboratory, Berkeley, California. It is a companion study to one performed by the Passive Solar Group, ASD, at Lawrence Berkeley Laboratory. The purpose of the study was twofold: first, a comparison was made of simulated results with measured data taken by others from test cells of differing wall constructions at Gaithersburg, MD, and Tesuque Pueblo, NM; and second, a comparison was made of two computer simulations of a prototypical residence when using the programs to characterize the effects of wall thermal mass. The results indicate that the DOE-2 Computer Program for Building Energy Analysis and the Building Loads Analysis and System Thermodynamics (BLAST) programs give similar results and that DOE-2 closes within a reasonable tolerance (plus or minus 20%) measured data from the test cells.

48
Birdsall, B.E., W.F. Buhl, R.B. Curtis, A.E. Erdem, J.H. Eto, J.J. Hirsch, K.H. Olson, and F.C. Winkelmann, Lawrence Berkeley Laboratory, Berkeley, CA

The DOE-2 Computer Program for Thermal Simulation of Buildings

AIP Conference Proceedings 135(1):642-649 (1985, November 25)

Purpose of the study was twofold. First, a comparison was made of simulated results with measured data taken by others from test cells of differing wall constructions at Gaithersburg, MD, and Tesuque Pueblo, NM. Second, a comparison was made of two computer simulations of a prototypical residence when using the programs to characterize the effects of wall thermal mass. The results indicate that the DOE-2 Computer Program for Building Energy Analysis and the Building Loads Analysis and System Thermodynamics (BLAST) programs give similar results and that DOE-2 closes within a reasonable tolerance (plus or minus 20%) to measured data from the test cells.

49

Boggs, D.L., and W.F. Stoecker, University of Illinois at Urbana, Department of Mechanical and Industrial Engineering, Urbana, IL

Performance and Simulation of Once-Through and Separating Cycles Using Nonazeotropic Refrigerant Mixtures

ORNL/Sub-81/7762/5&01; UILU-ENG-86-4005; 101 pp. (1986, June)

A simulation program developed at the University of Illinois at Urbana-Champaign was refined to match the performance of an experimental refrigeration facility located in the laboratory of the Department of Mechanical and Industrial Engineering in which the working fluid was a nonazeotropic mixture of two refrigerants, R-12/R-114. When simulating this two-evaporator system the program provided insight on how to control the physical system while independently regulating the refrigerating capacity and temperature level of each evaporator. A further role of the simulation program was to identify the extent to which the reduction in heat-transfer coefficients affected the cycle efficiency. The reduction in compressor power for given refrigeration loads and temperatures when using R-12/R-114 mixtures was of the order of 2% in comparison to using R-12 alone. Were it possible to maintain the same heat-transfer coefficients as with R-12 alone, the simulation program predicted an energy saving of 3.5%.

50

Boone, P.M., T.G. Rossman, and J.M. Daisey, New York University Medical Center, New York, NY

The Genotoxic Contribution of Woodsmoke to Indoor Respirable Suspended Particles

DOE/ER/60493-1 (Vol. 1); CONF-870853; Indoor Air '87, Indoor Air Quality and Climate - Volume 1: Volatile Organic Compounds, Combustion Gases, Particles and Fibres, Microbiological Agents, B. Seifert, B., H. Esdorn, M. Fischer, H. Rueden, and J. Wegner, (eds.), Proceedings of the Fourth International Conference, Berlin, Federal Republic of Germany, August 17-21, 1987; (pp. 524-528) (1987)

The genotoxicity of dichloromethane extracts of indoor respirable particulate matter, with and without woodsmoke, were measured with the Microscreen bioassay. Non-systematic changes in background dose-response curves upon metabolic activation and the addition of woodsmoke suggest numerous non-combustion sources of toxic, mutagenic, and metabolically active compounds exist in homes.

51

Briggs, R.S., Pacific Northwest Laboratory, Richland, WA

Energy Cost and Building Cost Model: An Approach to Building Cost Effectiveness and Responsiveness into the Targets

PNL-SA-13842

52

Briggs, R.S., Pacific Northwest Laboratory, Richland, WA

Cutting Energy Costs in Multifamily Housing: Practical Case Studies for the Building Owner and Developer

PNL-5966; 197 pp. (1986, August)

This book is based on an expert evaluation of nine existing and three proposed multifamily housing projects across the U.S. The existing buildings include three lowrise projects (three to four stories), six midrises (five to seven stories), and three highrise buildings (nine to thirty-nine stories). Two projects were designed and built in the late 1950's, two in the late 1960's, and five late in the "energy-crisis" of the 1970's. The existing projects range from municipally subsidized elderly housing, to HUD Section-8 suburban developments, to luxury urban highrise buildings. The three "future" buildings, designed by the NAHB research team, were based on trends anticipated in the multifamily industry by IREM and NAHB leaders, over the next five years. The key trends identified were: downsizing of units (by 10 to 20%); increased project size (in number of units), denser developments (more midrise and highrise projects), and increased amenities - all in the context of more affordable housing.

53
Brown, M.A., L.G. Berry, D.L. White, and P. Zeidler, Oak Ridge National Laboratory, Oak Ridge, TN; Florida Power and Light Company, Miami, FL

The Role of Auditor Sales Effectiveness in Residential Conservation Incentive Programs: A Case Study at Florida Power and Light

ORNL/CON-201; 73 pp. (1986, August)

The purpose of this study was to better understand determinants of auditor sales effectiveness in utility energy conservation programs. More specifically, Oak Ridge National Laboratory joined with the Florida Power and Light Company (FPL) to examine characteristics of their Marketing Service Representatives (MSRs) and the effect of such characteristics on customer participation in four residential conservation incentive programs. The four programs are: the Conservation Water Heating Program (CWHP), the Residential Ceiling Insulation Program (RCIP), the Residential Window Treatment Program (RWTP), and the Home Energy Loss Prevention Program (HELP) which offers a package of low-cost measures. The study findings suggest that the needs of the households offered incentives are the primary determinants of program participation, but that the characteristics of the MSR are also influential.

54
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An Evaluation of the Institute on Energy and Engineering Education

ORNL/TM-9482; 27 pp. (1985, April)

The Institute on Energy and Engineering Education has taken place annually since 1980, and has been an integral part of the Research Utilization (RU) Program of the U.S. Department of Energy's (DOE) Office of Buildings and Community Systems. This paper evaluates the Institute in terms of its stated goals and in light of the objectives of the RU Program. Support of the Institute is based on the premise that participating faculty will educate a generation of students who will implement building energy-related concepts and techniques in their own practices. The evaluation draws upon two types of data collected from participants. This first dataset was generated through questionnaires completed during the last day of each of the Institutes (N equal 129). The second dataset was developed from follow-up telephone discussions with a sample of 54 participants from the 1980 through 1983 Institutes. The overall conclusion of the evaluation is that the Institute has served its mission very well, and that by evolving in response to changes in the engineering professions and to energy technologies, it will continue to do so. Specific recommendations are made.

55
Brown, M.A., D.W. Jones, J.O. Kolb, and S.A. Snell, Oak Ridge National Laboratory, Oak Ridge, TN; University of Kentucky, Lexington, KY

Technology Transfer for DOE's Office of Buildings and Community Systems: Assessment and Strategies

ORNL/CON-202; 116 pp. (1986, July)

Technology transfer is viewed by authors as an ongoing government process of obtaining private sector and state and local government input in the development of R&D programs and of facilitating the use or R&D results by users. This report discusses: (1) the technology transfer problem faced by DOE's Office of Buildings and

Community Systems (BCS); (2) a process for determining how to transfer specific R&D products of the BCS Office; and (3) the pros and cons of five prototype technology-transfer strategies. The goal of the Office of Buildings and Community Systems is to increase the efficiency of energy use in the buildings sector. Technology transfer is critical to its mission.

56
Brown, M.A., E.J. Soderstrom, E.D. Copenhaver, and J.H. Sorensen, Oak Ridge National Laboratory, Oak Ridge, TN

A Strategy for Accelerating the Use of Energy-Conserving Building Technologies

ORNL/TM-9630; 30 pp. (1985, July)

To accelerate the use of energy-conserving building technologies in the far-flung, decentralized buildings industry, a strategy for more directed transfer of government research to public- and private-sector users has been implemented. The strategy involves a cycle of four sets of activities: (1) needs assessment; (2) development of transferable information; (3) outreach activities; and (4) feedback and evaluation. By employing this iterative technology transfer cycle and emphasizing trade and professional organizations as communication channels to and from users, it is hoped that research sponsored by the U.S. Department of Energy's Building Systems Division will be responsive to industry needs and accessible to the diverse participants in the buildings industry.

57
Brown, M.A., and D.L. White, Oak Ridge National Laboratory, Oak Ridge, TN

Impact Analysis of a Residential Energy Conservation Shared Savings Program: The General Public Utilities Experience

ORNL/CON-217; 69 pp. (1987, February)

In 1983 the General Public Utilities Corporation (GPU) initiated a novel shared savings program, the Residential Energy Conservation Action Program (RECAP), in four New Jersey and Pennsylvania communities. The program is administered through contracts between GPU and energy services companies. These companies install energy retrofit measures free-of-charge to all-electric GPU customers; in return they receive payments from the utility for the electricity savings that result from their retrofit work. In 1984, ORNL undertook an evaluation of the RECAP program, with funding from DOE and in-kind support from GPU. An evaluation of the process of implementing RECAP was conducted first (Brown and Reeves, 1985). Then attention turned to an assessment of the program's impacts, the electricity savings attributable to RECAP, customer satisfaction with the program, comfort benefits, use of the water heater control, and reliance on alternative heating fuels (Brown and White, 1986).

58
Brown, M.A., D.L. White, and S.L. Purucker, Oak Ridge National Laboratory, Oak Ridge, TN

Impact of the Hood River Conservation Project on Electricity Use for Residential Water Heating

ORNL/CON-238; 78 pp. (1987, October)

The Hood River Conservation Project (HRCP) was a two-year experiment in which residential customers were monitored for one year before and after the installation of conservation measures. Monitoring involved recording electricity use at 15-minute intervals for total consumption, space heat, and water heat. This report deals with the water-heater conservation results. The evaluation sought to: (1) determine electricity savings due to the installation of water-heater conservation measures; (2) quantify the savings attributable to each of the conservation measures (water-heater wrap, pipe wrap in the vicinity of the water heater, and low-flow showerheads); (3) quantify on- and off-peak savings; and (4) identify demographic and other determinants which correlate with savings.

59
Brunello, P., and R.C. Sonderegger, Universita di Udine, Institu di Fisica Tecnica,

Udine, Italy; Morgan Systems Corporation, Berkeley, CA

Performance Calculations of Residential Cooling Systems for Simplified Energy Analysis

Energy and Buildings 8(4):247 (1985)

The seasonal performance of space cooling systems depends on indoor and outdoor temperatures and humidities and on the ratio between actual cooling loads and cooling equipment size according to authors. This paper presents a simplified approach that derives the indoor wet-bulb temperature in closed form for both cases when the cooling system condenses water from the space and when it does not. This approach relies on a local linearization of the psychrometric chart in the region of interest for indoor comfort conditions. The predictions of the simplified method were compared with DOE-2 when calculating space cooling consumption for a residence in both a hot arid and in a hot humid climate.

60

Buhl, W.F., A.E. Erdem, J.H. Eto, J.J. Hirsch, and F.C. Winkelmann, Lawrence Berkeley Laboratory, Berkeley, CA

New Features of the DOE-2.1C Energy Analysis Program

CONF-850817; Building Energy Simulation, Proceedings of a Conference, Seattle, WA, August 21, 1985; (pp. 195-200) (1985, August 12)

Five new features of the DOE-2.1C building energy simulation program are presented. The features are: (1) user input of new algorithms in LOADS; (2) a sunspace-atrium model; (3) simulation of the powered induction unit HVAC system; (4) cogeneration simulation in PLANT; and (5) a new ECONOMICS program able to handle most utility rate schedules. The capabilities of each new feature are outlined and some details of the implementation or simulation techniques of each feature area briefly discussed.

61

Burch, D.M., et al., National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

The Effects of Interior Mass Surfaces on the Space Heating and Cooling Loads of a Single-Family Residence

NBSIR-86-3377 (1986, May)

62

Burke, J.C., et al., Oak Ridge National Laboratory, Oak Ridge, TN

Summary and Evaluation of Field Performance Data on Unitary Heat Pumps

ORNL/Sub-85/00219/1 (1986, April)

Thirty-eight programs involving over 700 heat pump units were identified and categorized in three levels based on the parameters measured. Level I programs (nearly 600 units) measured energy input normally using utility load research methods, to obtain semi-quantitative performance information and "hands on" operating experience. In Level II programs (almost 150 units) both energy input and output were obtained allowing estimation of HSPF. However the output determination methods (usually flip-flop or estimation of building load) involved 10 to 20% uncertainty in the heating mode and were not normally suitable for cooling. Level III programs (less than 60 units) involved measurement of input, output and at least some isolation of dynamic losses due to part load cycling and frost/defrost. Key reasons cited for needing heat pump field test data were load management, consumer information, product design and model validation. The major types of thermal performance data needs reported included energy consumption and savings (HSPF and SEER), load profiles, and information on advanced designs. Reliability and maintenance were also of great interest in addition to thermal performance.

63

Busch, J.F., Lawrence Berkeley Laboratory, Berkeley, CA

A Comparison of Building Thermal Models Using Measured Data

LBL-20461 (1986, June)

64

Busch, J.F., and A.K. Meier, Lawrence Berkeley Laboratory, Berkeley, CA

Monitored Performance of New Low-Energy Homes - Updated Results from the BECA-A Data Base

LBL-18306; 20 pp.; CONF-850306; Solar Energy, Proceedings of a Conference, Knoxville, TN, March 25, 1985 (1985, March)

Energy consumption data construction details and operating characteristics of over three hundred new, low-energy homes were compiled and analyzed. Over two thirds of the buildings incorporated solar features. A sequence of standardization procedures were developed to compare the energy performance of the buildings. The procedures adjusted the reported heating energy consumption for variations in the climate, floor area, internal gains, and reported indoor temperature. Two indicators of thermal performance were developed, the balance temperature and a k-value, which roughly corresponds to the overall UA of the building but also includes the ability of the house to exploit solar gains and thermal mass.

65

Busching, H.W., K.R. Amirkhanian, and G.E. Courville, Oak Ridge National Laboratory, Oak Ridge, TN

Ultraviolet Radiation Testing of Roofing Systems

ORNL/Sub-85/27453/1 (1985)

The Roof Research Center (RRC), a DOE national user facility planned for construction at Oak Ridge National Laboratory, will be used for studying roof systems subjected to accelerated testing. A review of relevant literature concerning ultraviolet radiation (UV) and related testing and equipment was completed to determine the feasibility of using this proposed facility for artificially-induced ultraviolet weathering of twelve by twelve foot roof systems that will be tested for periods of up to eight weeks.

66

Busching, H.W., G.E. Courville, M. Dvorchak, and J. McCorkle, Oak Ridge National Laboratory, Oak Ridge, TN

Low-Slope Roofing Research Needs - An ORNL Draft Assessment

ORNL/M-340; 35 pp. (1987, August)

The Low-Slope Roofing Research Needs Agenda is a resource document prepared by the Roofing Industry Research Advisory Panel. The document will aid the Panel in developing recommended research priorities and schedules for the Roof Research Center established by the U.S. Department of Energy at Oak Ridge National Laboratory (ORNL). The Roof Research Center, partially in operation now and scheduled for full operation in mid-1988, provides the roofing industry with a unique test facility capable of careful, on-line measurements on whole roof systems under controlled, simulated in-service conditions. This type of systems testing, however, is not well-developed in the roofing industry where, customarily, careful measurements are only made to assess individual material properties under design conditions and systems testing generally is limited to "performance testing"; that is, exposing roof systems to typical or accelerated environments and observing or measuring the time integrated effects on various components. The Panel, using the roof systems concerns listed within the document and being cognizant of priorities and of the capabilities of the experimental apparatus, will rank the specific projects that are relevant to the roofing industry and that utilize the unique capabilities of the Roof Research Center.

67

Busching, H.W., and J.P. Porcher, Oak Ridge National Laboratory, Oak Ridge, TN

Roofing Industry Perspective and Research Capability

ORNL/Sub-82/22293/2 (1985, March)

This report provides a qualitative and numeric summary of the U.S. roofing industry with emphasis on its infrastructure and research profile. Descriptive models of the following activities are presented: roof design, pre-construction activities, roof construction and acceptance, roof maintenance, resolution of roof complaints, and dissemination of roofing information. Principal groups that deal with roof industry issues are identified together with categories of generic roof research. A brief discussion of the results of a survey of industry-sponsored roofing research is presented, research equipment and approximate research budgets are given, and an analysis of articles on roofing research is included.

68
Bushby, S.T., and G.E. Kelly, National Bureau of Standards, Washington, DC

Comparison of Direct-Digital-Control and Pneumatic-Control Systems in a Large Office Building

NBSIR-88-3739; PB-88-215470/XAB; 56 pp. (1988, March)

A distributed, microprocessor-based direct digital control (DDC) energy management and control system was developed and installed in an eleven story office building in Gaithersburg, Maryland. Over a period of one year the performance of this system under various control strategies was investigated along with the performance of a conventional pneumatic control system. The quality of control and performance characteristics for the two control systems were compared. The results indicate that a pneumatic system can perform as well as a DDC system but more effort is required to maintain system performance.

69
Butcher, T., Y. Celebi, and M. Piraino, Brookhaven National Laboratory, Upton, NY

Evaluation of the Low Temperature Heat Exchanger Fouling Problem: Results of Studies on Soot Production and Condensing System Fouling (Recovery of Latent Heat of Vaporization of Moisture)

BNL-51810; 92 pp. (1984, June)

The development of condensing heat exchangers for oil-fired heating equipment would yield a significant improvement in thermal efficiency. Soot production by oil burners, however, could lead to serious fouling problems in these systems. The objectives of this study were to investigate the causes of fouling in oil-fired condensing systems and to evaluate the need for the development of advanced oil burners. Tests were done to evaluate the effect of operating conditions on start-up and shutdown smoke production in both noncondensing and condensing furnaces. Modern retention head burners which are commonly used in the U.S. were included as well as one European burner with some different design features. These features included the head design, a fuel shut-off in the nozzle tip, and nozzle heating. This burner was found to produce less smoke on start-up and shutdown than the common U.S. burner. Fouling studies were done on both types of burners under cyclic conditions with relatively low excess air (10% CO2) and continuous induced draft. Soot deposition did not cause any change in system thermal performance although soot deposition was heavier than would be expected with a noncondensing system. Tests were also done on the effects of fuel quality on soot production. Measurement techniques for soot included the common Bacharach smoke spot test, optical opacity, and filtration (EPA method 5).

70
Butcher, T., Y. Celebi, M. Piraino, and R.J. McDonald, Brookhaven National Laboratory, Upton, NY

Results of Studies on Soot Production and Fouling in Oil-Fired Condensing Systems

BNL-39265; 21 pp.; CONF-860106; Proceedings of the Semiannual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, San Francisco, CA, January 19, 1986; ASHRAE Transactions 92(1B):683-694 (1986, January)

The development of condensing heat exchangers for oil-fired heating equipment would yield a significant improvement in thermal efficiency. Soot production by oil burners, however, could lead to fouling problems in these systems. Results are reported on tests done to evaluate the effect of operating conditions on start-up and shutdown smoke production in both noncondensing and condensing furnaces. Parameters studied included burner excess air, draft condition, operating cycle, and heat exchanger system resistance. During start-up there is a momentary pressure peak in the combustion chamber as gas expansion occurs. This peak reduces fan airflow, leading to fuel-rich conditions and soot. After shutdown heavy soot can also be formed in condensing systems unless there is a brief, forced airflow through the combustion chamber. In the absence of an airflow, heat soak-back from the combustion chamber overheats the fuel nozzle assembly leading to afterdrip and soot formation. Modern retention head burners, which are commonly used in the U.S., were included as well as one European burner with some different design features. These features included the head design, a fuel shut-off in the nozzle tip, and nozzle heating. This burner was found to produce less smoke on start-up and shutdown than the common U.S. burner.

71
Byrne, S., Y.J. Huang, R.L. Ritschard, and D.M. Foley, Lawrence Berkeley Laboratory, Berkeley, CA

Potential for Wind Induced Ventilation to Meet Occupant Comfort Conditions

LBL-19818; 20 pp.; CONF-8509126; Hot Humid Climate, Proceedings of a Conference, College Station, TX, September 24-26, 1985 (1985, July)

This paper describes a single graphic tool that enables a building designer to evaluate the potential for wind induced ventilation cooling in several climate zones. Long term weather data were analyzed to determine the conditions for which available wind speed can be used to meet occupant comfort conditions. By calculating the change in enthalpy produced by a typical residential air conditioner during those hours when an occupant is uncomfortable, we were able to estimate the impact of natural ventilation on building cooling load. The graphic presentation of the results allows a designer to determine the potential energy savings of increasing the ventilation air-flow rate as well as the orientation of building openings that will maximize ventilation cooling of the building occupants.

72
Byrne, S., and R.L. Ritschard, Lawrence Berkeley Laboratory, Berkeley, CA

Thermal Mass in Exterior Walls of Residential Buildings

LBL-19041 (1986)

73
Cairns, E.J., and A.H. Rosenfeld, Lawrence Berkeley Laboratory, Berkeley, CA

Center for Building Science: Annual Report - FY 1986

LBL-24292; 171 pp. (1987, May)

The Center for Building Science consists of four programs in the Applied Science Division of the National Bureau of Standards; energy analysis, buildings energy systems, windows and lighting, and indoor environment. It was established to provide an umbrella so groups in different programs with similar interest could combine to perform joint research, developed in new research areas. An overview of FY 1986 research and program areas such as new buildings components, computer models, and data and information systems are discussed.

74
Catan, M.A., Brookhaven National Laboratory, Upton, NY

Optimized Ground Coupled Heat Pump Mechanical Package

BNL-36225; 8 pp. (1987)

This project addresses the question of how well a ground coupled heat pump system could perform with a heat pump which was designed specifically for such systems operating in a northern climate. Conventionally, systems are designed around water source heat pumps which are not designed for ground coupled heat pump application. The objective of the project is to minimize the life cycle cost for a ground coupled system given the freedom to design the heat pump and the ground coil in concert. In order to achieve this objective a number of modeling tools were developed which will likely be of interest in their own right.

75

Catan, M.A., Brookhaven National Laboratory, Upton, NY

Optimized Ground-Coupled Heat Pump Mechanical Package

CONF-841231; Research and Development on Heat Pumps for Space Conditioning Applications, Proceedings of the DOE/ORNL Heat Pump Conference, Washington, DC, December 10, 1984; (pp. 113-120) (1985, August)

The question of how well a ground coupled heat pump system could perform with a heat pump which was designed specifically for such systems operating in a northern climate is discussed. Conventionally, systems are designed around water source heat pumps which are not designed for ground coupled heat pump application. The objective of the project is to minimize the life cycle cost for a ground coupled system given the freedom to design the heat pump and the ground coil in concert. In order to achieve this objective a number of modeling tools were developed which will likely be of interest in their own right. The system which was optimized was a horizontal earth coil in a given house in the Pittsburgh area. The types of components used in the heat pump are essentially conventional. A computer model, created at Oak Ridge National Laboratory (ORNL), was used to predict heat pump performance for specified configuration and operating conditions. A pre-determined set of design parameters is automatically altered by a constrained minimization program, to find the combination for which the highest COP is predicted by the heat pump model.

76

Catan, M.A., and V.D. Baxter, Brookhaven National Laboratory, Upton, NY

An Optimized Ground-Coupled Heat Pump System for Northern Climate Applications

CONF-850606; Proceedings of the Semiannual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Honolulu, HI, June 23-26, 1985; ASHRAE Transactions 91(2B):1185-1201 (1985)

This paper addresses the question of the performance of a ground coupled heat pump (GCHP) system with a water-source heat pump package designed expressly for such systems operating in a northern climate. The project objective was to minimize the life-cycle cost of a GCHP system by optimizing the design of both the heat pump package and the group coil in concert. In order to achieve this objective, a number of modelling tools were developed to analyze the heat pump's performance and cost, and the ground coil's performance.

77

Chen, F.C., Oak Ridge National Laboratory, Oak Ridge, TN

An Overview of the Stirling Engine Heat Pump Program

CONF-8804100; Research and Development on the Heat Pump for Space Conditioning Applications, Proceedings of the Second DOE/ORNL Heat Pump Conference, Washington, DC, April 17-20, 1988, 225 pp. (1988)

Recent developments in activities on the Stirling engine-driven heat pump program are summarized. These activities are sponsored by the Department of Energy (DOE) through ORNL. Enhanced technology options guided by value engineering principles are being pursued toward the development of an economically viable household engine-driven heat pump.

78
Chen, G., Oak Ridge National Laboratory, Oak Ridge, TN; Sunpower, Inc., Athens, OH

Free-Piston Stirling Engine Magnetically Coupled Heat Pump: Critical Component Evaluation - Phase 1, Final Report

ORNL/Sub-86/SA578/1; 46 pp. (1989, August)

The Free-Piston Stirling Engine (FPSE) Magnetically Coupled Heat Pump Program at Sunpower involves the development of a FPSE/magneticcoupling/compressor(FPSE/MC/C) assembly for a gas residential heat pump application. The objectives of phase 1 were: (1) to evaluate the feasibility and characteristics of critical components such as a linear magnetic coupling and hermetic sealing, (2) to demonstrate through tests the performance of a magnetic coupling/compressor assembly, and (3) to evaluate the system concept design by applying an air-charged FPSE.

79
Chen, N.C.J., and F.P. Griffin, Oak Ridge National Laboratory, Oak Ridge, TN

Liner Harmonic Analysis of Free-Piston Stirling Engines

ORNL/CON-172; 104 pp. (1986, June)

The equations that govern the behavior of free-piston Stirling engines are nonlinear differential equations. Traditional solution methods have been time-stepping integrations that can be plagued by numerical instabilities and can use large amounts of computer time. Closed-form analytical solutions are possible if the working gas behaves isothermally or if the nonlinear terms in the governing equations are replaced with accurate approximations. An almost closed-form solution method, called the linear harmonic analysis (LHA), has been developed for free-piston Stirling engine applications by representing all of the periodic variables with harmonic functions.

80
Chen, N.C.J., F.P. Griffin, and C.D. West, Oak Ridge National Laboratory, Oak Ridge, TN

Simplified Analysis of Stirling Engines and Heat Pumps

CONF-841231; Research and Development on Heat Pumps for Space Conditioning Applications, Proceedings of the DOE/ORNL Heat Pump Conference, Washington, DC, December 10, 1984; (pp. 183-191) (1985, August)

A linear harmonic analysis (LHA) of Stirling engines and heat pumps is presented in outline form. The objectives of the analysis are: (1) to understand why free-piston Stirling engines (FPSE) for heat pumps do not work as well as expected, and (2) to understand the nature of the loss mechanisms in the FPSE heat pump systems so that improvements can be made and the full potential of these machines realized. It is concluded that LHA is a powerful and accurate tool that is well suited to the analysis of Stirling machines and that it applies to both kinematic and free-piston engines.

81
Childs, K.W., Oak Ridge Gaseous Diffusion Plant, Oak Ridge, TN

Analysis of Calibrated Hot Box Data for Three Concrete Walls

K/CSD/TM-56; 51 pp. (1985, September)

Three walls constructed of concrete with different densities were tested in a calibrated hot box at the Construction Technology Laboratories of the Portland Cement Association. The observed dynamic performance of these walls was not in good agreement with analytical solutions based on the assumption of linear heat conduction through the walls. Several sources of potential errors in the data from the hot box were explored. While some of these errors do appear to be real, they do not fully explain the discrepancy between experimental and analytical results. The experimentally determined values of the specific heats for the three concrete walls were identified as the most likely cause for the discrepancies. This report presents the analysis of the data from the hot box experiments and suggestions for future investigation.

82
Childs, K.W., Oak Ridge Gaseous Diffusion Plant, Oak Ridge, TN

The Use of Roof Temperature Modeling to Predict Necessary Conditions for Locating Wet Insulation with Infrared Thermography

K/CSD/TM-58; 45 pp. (1985, November)

In low-sloped roofing systems using porous insulation, the presence of water can significantly degrade thermal performance. For this reason, it is desirable to develop a reliable method for detecting the presence of water in a roofing system. Because of the different thermal characteristics of wet and dry insulation, there is often a surface temperature differential between areas containing wet insulation and areas containing dry insulation. Under the right circumstances, the areas of wet insulation can be detected by means of infrared sensing techniques. These techniques have already gained widespread acceptance, but there is still some uncertainty as to what are appropriate environmental conditions for viewing. To better define the conditions under which infrared techniques can distinguish between areas of wet and dry insulation, a one-dimensional, transient heat transfer model of a roofing system was developed. The model considers conduction through the roof, insolation on the surface, radiant exchange between the roof and sky, convective heat transfer between the roof and air, and the influence of trapped moisture on the thermal properties of the insulation. A study was undertaken using this model to develop an easily-applied technique for prediction of necessary conditions for locating wet roof insulation using infrared thermography.

83
Choi, U.S., R. Johnson, and S. Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

The Impact of Daylighting On Peak Electrical Demand

Energy and Buildings 6(3):387-399 (1984)

A complete analysis of the cost-effectiveness of daylighting strategies should include the impact of daylighting on peak electrical demand as well as on energy consumption. An hour-by-hour building energy analysis program was used to study the thermal and daylighting impacts of fenestration on peak demand. Fenestration properties and lighting system characteristics were varied parametrically for office buildings in Madison, WI and Lake Charles, LA. Peak electrical demand was disaggregated by component and by zone, monthly patterns of peak demand were examined, and impacts of fenestration performance on chiller size were studied. The results suggest that for daylighted office buildings, the peak electrical demand results from a complex trade-off between cooling load due to fenestration parameters, lighting load reductions due to glazing and lighting system characteristics. Lowest peak demands generally occur with small to moderate size apertures. With daylighting, peak electrical demand is reduced by 10 to 20% for the building configuration studied (37% perimeter zone, 63% core zone). This work indicates that solar gain through fenestration must be effectively controlled in order to realize the potential of daylighting to significantly reduce peak electrical demand.

84
Christian, J.E., Oak Ridge National Laboratory, Oak Ridge, TN

ASHRAE 90.2 New Residential Building Standard Thermal Mass Update

(1985, February)

85
Christian, J.E., Oak Ridge National Laboratory, Oak Ridge, TN

Thermal Cooling Performance and Comfort in a Massive Test Building

(1985, May)

86
Christian, J.E., Oak Ridge National Laboratory, Oak Ridge, TN

Thermal Mass Program Results Relevant to Florida Energy Code Revision Process

(1985, May)

87
Christian, J.E., Oak Ridge National Laboratory, Oak Ridge, TN

Foundation Futures: Energy Saving Opportunities

CONF-880627; Proceedings of the Annual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Ottawa, Canada, June 25-29, 1988; (27 pp.) (1988)

Significant energy savings will result from compliance to the foundation insulation recommendations in ASHRAE Standard 90.2P, "Energy Efficient Design of New, Low-Rise Residential Buildings". This paper summarizes an assessment of current U.S. energy savings from foundation insulation and estimates future savings resulting from broad-scale adoption of ASHRAE 90.2P. According to the authors the assessment is based on the premise that the detailed analysis behind ASHRAE 90.2P and its systematic method of determining insulation levels in a balanced manner will allow it to become the accepted base energy performance standard for all residential construction.

88
Christian, J.E., Oak Ridge National Laboratory, Oak Ridge, TN

Detailed Thermal Performance Measurements and Cost Effectiveness of Earth-Sheltered Construction: A Case Study

ORNL/CON-186; 48 pp. (1985, September)

Earth-covering, solar gain, and massive construction team up to provide an energy-efficient, durable, and comfortable building. However, the question of whether these energy-saving features are cost effective still remains. The Joint Institute Dormitory, a 372 sq m (400 gross sq ft) office-dormitory equipped with 100 sensors and a data acquisition system designed to store hourly thermal performance data from February 1982 to October 1984, provides a penetrating look at a number of energy-saving construction techniques. One of the objectives for collecting these data is to determine cost effectiveness based on field thermal performance of the whole building, including an earth-covered roof, bermed north wall, insulated concrete slab floor, structural thermal mass coupled with direct solar gain, and reflective insulating blinds. This report uses the detailed measurements as the bases for estimating annual energy savings with respect to more conventional energy-conscious wood-frame residences. The energy savings along with incremental cost estimates are used to determine cost effectiveness.

89
Christian, J.E., Oak Ridge National Laboratory, Oak Ridge, TN

Building Foundations Research Agenda

ORNL/CON-222; 87 pp. (1986, December)

The Building Foundation Research Program fulfills the short-term needs of delivering available information on energy-efficient foundation construction practices to lead builders and also fulfills the longer-term needs of substantiating an array of design tools based on well-characterized test site data and validated simulation models. The primary research focus is a set of foundation handbooks targeted at builders and designers.

90
Christian, J.E., Oak Ridge National Laboratory, Oak Ridge, TN

Impact of CFC Restrictions on U.S. Building Foundation Thermal Performance

ORNL/CON-245; 68 pp. (1987, December)

A significant increase in the use of foundation insulation had been expected as a result of the near completion of ASHRAE 90.2P, New Building Energy Efficiency Standard, and the publication of several Department of Energy foundation design tools. The work statement for this analysis called for an initial impact analysis on energy conservation goals and a foundation research plan to mitigate the impacts of restricting the use of CFCs in foundation insulation systems. This report addresses quantitatively the energy-saving impacts at the state level of CFC restrictions on foundation insulation and concludes that the total impact could be anywhere from near zero to 0.8 quad in the year 2010, with the most likely impact being about 0.13 quad/year.

91

Christian, J.E., and D.L. McElroy, Oak Ridge National Laboratory, Oak Ridge, TN

Results of Workshop to Develop Alternatives for Insulations Containing CFCs Research Project Menu

ORNL/CON-269; 140 pp. (1988, December)

Sixty-nine individuals from 43 organizations impacted by CFC restrictions in the production of insulations met for two days to produce a relative comprehensive and prioritized list of research needs. This report presents a prioritized research list of programs identified by individuals. Top projects were: development of a database of physical properties of substitute blowing agents; protocol to predict thermal performance of cellular foam insulation products; identifying new blow agents; CFC manufacturing recovery processes; low K standard reference processes; Ion K standard reference material; and environmentally acceptable blowing agents.

92

Chwalouski, M., D.A. Didion, and P.A. Domanski, National Bureau of Standards, Washington, DC

Verification of Evaporator Computer Models and Analysis of Performance of an Evaporator Coil

CH-89-23-1; ASHRAE Transactions 95(1) (1989, January)

This report contains a verification of computer algorithms to predict the capacity of an evaporator coil used in an air-conditioning application. Three computer programs and a major coil manufacturer's catalog were utilized. Two direct-expansion, V-shaped indoor coils and a flat coil positioned at different face angles with horizontal airflow were tested at two refrigerant saturation temperatures. Tests results, comparison with models and catalog predictions, and the reasons for differences were discussed.

93

Claar, C.N., R.P. Mazzucchi, and J.A. Heidell, Pacific Northwest Laboratory, Richland, WA

Project on Restaurant Energy Performance: End-Use Monitoring Report and Appendices

PNL-5462; 154 pp. (1985, May)

The rapid increase in the costs of energy supplies over the past decade has placed increased emphasis on the efficient use of energy in commercial buildings. Studies conducted by the Department of Energy (DOE) and others have revealed that significant amounts of energy can be conserved in a cost-effective manner through proper selection and application of conservation principles. This document provides a description of a project undertaken as part of the Commercial Building Energy Use and Design Program, a multiyear research program sponsored by the Department of Energy, Architectural and Engineering Systems Branch, Building Systems Division. The program is managed by Pacific Northwest Laboratory (PNL), operated for DOE by Battelle Memorial Institute. Under this project PNL and its contractors collect and analyze metered energy performance data from a series of commercial buildings to develop a reliable and publicly available data base for the buildings community.

94

Clark, D.R., and W.B. May, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

HVACSIM+ Building Systems and Equipment Simulation Program - User's Guide

NBSIR-85-3243; PB-86-130615/XAB; 203 pp. (1985, September)

HVACSIM+ is a modular, non-proprietary computer simulation package developed at the National Bureau of Standards. The package consists of a general-purpose modular simulation program called MODSIM, a library of component models specific to building systems, and a simulation editor called HVACGEN. The latter is used to facilitate the creation and modification of simulation descriptions. HVACSIM+ is designed to allow detailed simulation of entire building systems or portions of such systems. This includes the heating, ventilating, and air conditioning (HVAC) system, the equipment control system, the conditioned zones within a building, the building shell, and the dynamic interactions among these subsystems. This document describes the procedures for installing HVACSIM+ on a particular computer, for setting up a simulation description using HVACGEN, and for running a simulation using MODSIM.

95
Clarke, J.A., and A.D. Irving, University of Stratclyde, Glasgow, Scotland; Rutherford Appleton Laboratory, Chilton, United Kingdom

Building Energy Simulation: An Introduction

Energy and Buildings 10(3):157 (1988)

Considerable advances in the application of computers and building design have been demonstrated in recent years which offer a more integrated approach to computer-aided building design. The objective of this paper is to describe the state-of-the-art in building energy simulation and to indicate future development trends. Building, plant, air flow, control, and human models are some of the elements of building energy simulation, presented in this article.

96
Cleary, P.G., Lawrence Berkeley Laboratory, Berkeley, CA

Monitoring Capabilities of Energy Management Systems in Commercial Buildings

LBL-23887; 14 pp.; CONF-870620; Proceedings of the Annual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Nashville, TN, June 28, 1987 (1987, June)

The Konsolen building is a high-thermal-mass 57-unit apartment building on the outskirts of Stockholm, Sweden. It is part of the Stockholm Project, a full-scale demonstration of energy-saving techniques. A large number of sensors were installed in the building for research purposes. Energy Management Systems outputs of total electricity use, heat output from heat pumps, and heat supplied by the district-heating mains were monitored. Detailed data and results are presented.

97
Cleary, P.G., and R.F. Szydlowski, Lawrence Berkeley Laboratory, Berkeley, CA

In-Situ Measurement on Refrigerators

LBL-23542 (1988)

98
Collins, B.L., and J.A. Worthey, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Lighting for Meat and Poultry Inspection

Journal of the Illuminating Engineering Society (p. 21) (1985)

99
Conlin, F., W.S. Johnson, S.D. Wix, and R.B. Bannerot, Alternative Energy Corporation, Research Triangle Park, NC

A TRNSYS/GROCS Simulation of a Horizontal-Coil Ground-Coupled Heat Pump

CONF-850306; Solar Energy, Proceedings of a Conference, Knoxville, TN, March 25, 1985; (pp. 65-73) (1985)

The ground-coupled heat pump system in the University of Tennessee's TECH house I in Knoxville, TN has been modeled using TRNSYS/GROCS and the results have been compared with actual performance data for both the 1982-1983 heating season and the 1983 cooling season. Hourly measurements of various ground temperatures, conditioned space temperatures, power requirements and heat transferred to or from the ground and the conditioned space were made. Results indicate that the model prediction is within 5% of the measured seasonal performance factor for both the summer and winter season. Parametric studies were undertaken to examine the effect of ground coil length, soil thermal conductivity, and heat pump performance rating on the overall seasonal performance of the system. As expected, overall performance increases with improved heat pump performance and increased soil thermal conductivity while the coil length shows an optimum value due to the increase of pumping power with length.

100
Copenhaver, E.D., Oak Ridge National Laboratory, Oak Ridge, TN

Use of Broker Organizations in Technology Transfer and Research Utilization for the Building Industry

ORNL/TM-9581 (1985, December)

The diversity and fragmentation of the building industry and differences in institutional structures can be formidable problems in the transfer of technology to the building industry from government-sponsored research. To assist the Department of Energy in functioning more effectively as a catalyst in the research utilization process, this study focuses on improving the understanding of existing organizations, their transfer systems, and their interactions. Over 450 organizations were identified as potential brokers of technology transfer and research utilization between government and the building industry. Transfer mechanisms used and interactions and recommendations for additional research on technology transfer utilizing brokers are outlined.

101
Courville, G.E., Oak Ridge National Laboratory, Oak Ridge, TN

Thermal Mass in Building Envelope Systems

(1985, May)

102
Courville, G.E., Oak Ridge National Laboratory, Oak Ridge, TN

Report from Oak Ridge National Laboratory - The Reporter

(1985, October)

This report provides information on the general characteristics and the use of various insulations in built-up roof systems. The emphasis is on system attributes; that is, issues that arise when insulations are considered in combination with other roof components and placed in the real outdoor environment. Short commentaries on generic insulation types and a partial list of good roofing practices are also provided.

103
Courville, G.E., Oak Ridge National Laboratory, Oak Ridge, TN

Briefings on Low Slope Roof System Meetings: Foreign Trip Report, June 4, 1989 - June 15, 1989

ORNL/FTR-3307; 13 pp. (1989, June 28)

G.E. Courville chaired a meeting of the IEA Annex 19 on Low Slope Roofs held at the Chalmers University in Goeteborg, Sweden on June 6-7, 1989. Representatives from the United States, United Kingdom, Sweden Denmark, and Switzerland were in attendance. The Annex reviewed material prepared by different countries for the scheduled Annex document on "Good Practices for Design, Installation, and Maintenance of Insulated Roofs." The format for additional background data was agreed upon. On June 14, Courville presented a briefing for the

IEA/BCS Executive Committee on Annex Activities. Courville visited the Norwegian Building Research Institute (NBI). NBI built the world's first environmental chamber for roofs in the early 1970s and continue to be innovative in buildings research and development. They produce and sell an excellent grade of heat flux transducers and various laboratory testing equipment. E. Paulsen of NBI has developed a roof uplift test procedure that is potentially useful in the U.S. Courville visited with Roger Bonafont of Ruberoid Limited and Nick Cook of BRE. Both these groups have experience and laboratory data on uplift testing which will be conveyed to the Steering Committee for a workshop on Uplift Testing in the United States.

104

Courville, G.E., and J.V. Beck, Oak Ridge National Laboratory, Oak Ridge, TN

Measurement of Field Thermal Performance Parameters of Building Envelope Components

CONF-880627; Proceedings of the Annual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Ottawa, Canada, June 25-29, 1988; (33 pp.) (1988)

A new technique for analyzing fuel-derived thermal performance data is described; it is incorporated in a computer program called PROPOR. The technique utilizes modern computational methods and relies on recent advances in data acquisition. The data base contains temperature and heat flow information collected for expanded polystyrene (EPS) insulation in a built-up roof specimen.

105

Courville, G.E., J.V. Beck, T.H. Kuhn, and C.E. Hickov, Oak Ridge National Laboratory, Oak Ridge, TN; American Society of Mechanical Engineers, New York, NY

Techniques for In Situ Determination of Thermal Resistance of Light Weight Board Insulation

CONF-870816; Thermal Hydraulics of Severe Nuclear Reactor Accidents, Proceedings of the National Heat Transfer Conference, Pittsburgh, PA, August 9-12, 1987 (1987)

Four techniques for determining in situ thermal resistance of rigid board insulation installed in conventional low-sloped roofs are described and compared. Test results are presented to allow a comparison of the methods.

106

Courville, G.E., and J. Brewer, Oak Ridge National Laboratory, Oak Ridge, TN

Marketing Plan and Strategies - Roof Research Center (RRC)

ORNL/M-339; 47 pp. (1988, June)

The U.S. Department of Energy (DOE) has established a Roof Research Center at the Oak Ridge National Laboratory (ORNL). Currently, DOE supports a program that includes laboratory experimental work, analysis, industry assessments, development of measuring procedures, and field performance surveys. The facilities and capabilities of this program are now being made more generally available to the roofing industry through designation of the Roof Research Center (RRC) as a National Users Facility. Within this program, DOE will actively seek multiple sponsorship for projects. It is the purpose of this marketing plan to define a strategy to assure that sufficient outside funding will be attracted to the RRC. Current literature on the roofing industry, existing market research and interviews with industry experts were used to gain information needed in this report. Industry trends, historical research expenditures, product classes and manufacturers in the industry were identified. From this, a list of target firms for the RRC was devised, along with the major publicity influences of this market. The RRC was also analyzed to determine its objectives and capabilities. Opportunities and problems that might occur with outside industry funding were also identified so that these could be addressed in the marketing strategy.

107
Courville, G.E., and H.W. Busching, Oak Ridge National Laboratory, Oak Ridge, TN; Clemson University, Clemson, SC

Roof Research Center - A Preliminary Concept Paper

ORNL/CON-188; 39 pp. (1985, November)

The U.S. Department of Energy is placing a major new Roof Research Center at Oak Ridge National Laboratory. This Center is currently under design with completion scheduled for late 1987. The center will be designated as a National User Facility. This ensures that its unique capabilities will be accessible to all users on a priority basis. An industry-wide Advisory Panel will assist the Department of Energy in establishing priorities and setting schedules. The Center will house an Environmental Chamber capable of handling up to 12 ft by 12 ft roof specimens. Controlled parameters include temperature, humidity, rain, wind speed, and pressure differences. Detailed performance measurements and mathematical modeling will be emphasized. Experimental areas to be studied at the Center include heat transfer, membrane movement, roof fatigue, and moisture effects.

108
Courville, G.E., K.W. Childs, D.J. Walukas, P.W. Childs, and E.I. Griggs, Oak Ridge National Laboratory, Oak Ridge, TN; Tennessee Technological University, Cookeville, TN

Apparatus for Thermal Performance Measurements of Insulated Roof Systems

CONF-841202; Thermal Insulation, Materials and Systems, Proceedings of a Symposium, Dallas, TX, December 2, 1984; (20 pp.) (1984)

The U.S. Department of Energy conducted thermal performance measurements on low-slope roofs with a recently developed field test apparatus at Oak Ridge National Laboratory (ORNL). The apparatus accommodates four 4 ft by 8 ft test specimens and includes the measurement capabilities for specimen temperatures, temperature gradients, heat flows and moisture content. A weather station characterizes outdoor weather conditions. Tests underway include: (1) validation of a roof surface temperature model developed to study the effects of wet insulation; (2) measurement of temperature distributions and heat transfer in high R-value roofs; and (3) validation of an analysis of the effectiveness of high reflectance surfaces. Preliminary experimental results are presented and correlations between experiment and modeling are discussed.

109
Courville, G.E., K.W. Childs, D.J. Walukas, P.W. Childs, and E.I. Griggs, Oak Ridge National Laboratory, Oak Ridge, TN; Tennessee Technological University, Cookeville, TN

Thermal Performance Measurements of Insulated Roof Systems

CONF-8509137; Roofing Technology, Proceedings of the Second International Symposium, Chicago, IL, September 19, 1985; (16 pp.) (1985)

Oak Ridge National Laboratory has established a Roof Thermal Research Apparatus for carrying out thermal and hygric experiments on sections of low-sloped roofs. Test panels are exposed to a controlled temperature interior space and to the prevailing East Tennessee exterior environment. They are well instrumented and all data are stored and aided in the analysis by computer systems. Current experiments include studies of the effect of wet insulation on membrane temperature, thermal storage phenomena in built-up roof insulation, and the effects of varying surface reflectance on roof thermal performance.

110
Courville, G.E., A.O. Desjarlais, R.P. Tye, and C.R. McIntyre, Oak Ridge National Laboratory, Oak Ridge, TN; Dynatech Scientific, Inc., Cambridge, MA; Koppers Company, Inc., Monroeville, PA

A Comparison of Two Independent Techniques for the Determination of In-Situ Thermal Performance

CONF-871203; Insulation Materials, Testing and Applications, Proceedings of the 1987 Conference, Bal Harbour, FL, December 6, 1987; (30 pp.) (1987)

A parallel experiment has been performed on an insulated roof system installed in the Roof Thermal Research Apparatus at Oak Ridge National Laboratory. Separate sections of a 4 foot, by 8 foot test panel were evaluated for over 12 months. This paper discusses the instrumentation packages, sensor calibration procedures, and data collection and analysis methods of highlighting the differences between the independent techniques. A comparison of the independently derived thermal performance results is presented.

111
Courville, G.E., and W.R. Huntley, Oak Ridge National Laboratory, Oak Ridge, TN

Development of a Major Center for Roof Research in the United States

CONF-870901; Advancing Building Technology, Proceedings of the Tenth CIB Congress, Washington, DC, September 21, 1986; (9 pp.) (1986, September)

The United States Department of Energy (DOE) is building a major roof research facility at Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee. The purpose of the facility will be to carry out research to enhance the thermal performance and durability of low-slope roof systems. The centerpiece of the facility will be an environmental chamber capable of testing up to 3.8 m square roof sections under conditions of temperature, humidity, rain, and uplift air pressures encountered throughout the United States. Other features of this facility will be apparatus for thermophysical and chemical bench testing and a strong mathematical modeling capability. The facility will be designated as a National Users Facility, that is, it will be available to researchers from industry, academia, and other government agencies on a priority basis. DOE and ORNL will be assisted by an Industrial Review Panel in setting research priorities and arranging schedules. The Facility will be ready for use early in 1988. Facility design features and a preliminary schedule of experiments will be described in this paper.

112
Courville, G.E., J.O. Hylton, W.P. Murray, A. Blalock, and C.J. Remenyik, Oak Ridge National Laboratory, Oak Ridge, TN

Electric Field Probes for Quantitative Moisture Measurements in Building Materials

CONF-871271; Mechanisms and Measurement of Water Vapor and Liquid Water Amount Through Materials, Proceedings of a Symposium, Bal Harbour, FL, December 6, 1987; (24 pp.) (1987)

Three novel capacitance techniques for making moisture measurements in insulated roof systems are being studied at the Oak Ridge National Laboratory (ORNL). These are designated as the "Pin Probe," the "Thermocouple Probe," and the "Planar Probe." The Pin Probe, developed at the Massachusetts Institute of Technology (MIT), consists of two parallel lines of straight pins as the two probe electrodes. This is an intrusive probe that must be mounted within the system being tested. The Thermocouple Probe is also intrusive. Its use assumes that thermocouple junctions exist at known locations in the specimen for temperature measurements. The probe electronics allows high frequency capacitance measurements between thermocouples without interfering with their temperature measurement function. The third probe, the Planar Probe, is non-intrusive and consists of a series of equally spaced plate electrodes in a box that sits on the surface of the roof. These electrodes provide several independent electrical signals from overlapping depths within the roof system. An analysis procedure was developed to identify the electrical properties of successively deeper layers of material. Prototypes of each of these probes have been constructed and promising preliminary data are available. Probe calibration, circuit stability, and range of applicability are major outstanding issues that must still be addressed.

113

Courville, G.E., and J.O. Kolb, Oak Ridge National Laboratory, Oak Ridge, TN

Economic Analyses of Insulation Materials Used in Low-Slope Built-Up Roof Systems

ORNL/TM-9004; 141 pp. (1984, June)

A wide variety of rigid-board types of insulations are currently manufactured for use under membranes of built-up roof (BUR) systems on buildings with low slope roofs. The U.S. Air Force currently specifies one type of BUR insulation in reroofing its facilities within the continental United States. The primary goal of this study was to develop an evaluation method for future Air Force use in selecting rigid-board insulations. The method was to include roof performance requirements for a long-lived system with life cycle costs (LCC) comparable with the currently specified insulation-fibrous glass. Insulation thermal resistance values up to R-33 (sq ft/hr/deg F/Btu) were included in the range of investigation. This report describes the development of an LCC-based evaluation method for long-lived BUR insulations. The study emphasizes general performance requirements for a long-lived BUR system, and presents the results of 20-year energy costs and general recommendations for insulations on a comparable economic (LCC) basis over a range of R-10 to R-33. The economic justification of very high (up to R-33) insulation levels under BUR membranes is also evaluated on the basis of optimum economic levels and is found to have little or no justification above an R-25 level.

114

Courville, G.E., J.P. Sanders, and P.W. Childs, Oak Ridge National Laboratory, Oak Ridge, TN

Dynamic Thermal Performance of Lightweight Insulated Low-Slope Roof Systems

CONF-851202; Thermal Performance of the Exterior Envelopes of Buildings - III, Proceedings of the DOE-ORNL-ASHRAE-BTECC Conference, Clearwater Beach, FL, December 2, 1985, 1421 pp.; (30 pp.) (1985, December)

The thermal performance of an in-service roof is difficult to analyze because it is dominated by complex time-varying boundary conditions at the outer surface. The Roof Thermal Research Apparatus has been built at a national laboratory to provide accurate detailed measurements of thermal response of roof systems exposed to fixed interior conditions and to fully monitored East Tennessee weather on the outside. Absolute and comparative data will be presented for well-insulated (R-value about 17 h/sq ft/F/Btu) test panels of expanded polystyrene, fiberboard, isocyanate, and fibrous glass board insulation under built-up roof membranes. Issues discussed will include mass effects caused by differing insulation densities, R-value measurement, comparison to steady-state calculations, and the relative influence of solar, wind, and ambient temperature. Results will be compared to numerical solutions of the heat transfer analyses.

115

Courville, G.E., P.H. Shipp, T.W. Petrie, and P.W. Childs, Oak Ridge National Laboratory, Oak Ridge, TN

Comparison of the Dynamic Thermal Performance of Insulated Roof Systems

CONF-890584; Roofing Technology, Proceedings of the Ninth Conference, Gaithersburg, MD, May 4, 1989; (24 pp.) (1989)

The Large Scale Climate Simulator at the DOE-sponsored Roof Research Center has been used to provide data for a comparison of the thermal resistance of three common roof insulations over an extended range of temperatures using two different techniques; one steady state and the other transient. The insulations are fiberglass, expanded polystyrene (EPS), and phenolic foam board. R-values are determined for temperatures ranging from 10 deg F to 130 deg F. Results from the two techniques are in agreement with one another and both are within 5 percent of reference values for the insulations. The testing illustrates the flexibility of the Large Scale Climate Simulator.

116
Courville, G.E., and A. TenWolde, Oak Ridge National Laboratory, Oak Ridge, TN; Forest Products Laboratory, Madison, WI

Moisture Measurements in Buildings

CONF-8409266; Proceedings of the BTECC Moisture Workshop, Washington, DC, September 25, 1984; (12 pp.) (1984)

The need for measurement of in-situ moisture content in building-envelope components is discussed. Electric resistance techniques are most common. They are relatively inexpensive and their use is straightforward. However, calibration is very difficult and penetration into the system being tested is required. Two non-intrusive techniques, electrostatic capacitance and nuclear magnetic resonance, are currently being studied in the laboratory to assess their usefulness as quantitative tools.

117
Courville, G.E., and D.J. Walukas, Oak Ridge National Laboratory, Oak Ridge, TN; Gas Research Institute, Chicago, IL

Insulation System Basics for Built-Up Roofs

ORNL-6171 (1985, June)

This report provides information on the general characteristics and the use of various insulations in built-up roof systems. The emphasis is on system attributes; that is, issues that arise when insulations are considered in combination with other roof components and placed in the real outdoor environment. Short commentaries on generic insulation types and a partial list of good roofing practices are also provided.

118
Crawley, D.B., Pacific Northwest Laboratory, Richland, WA

Proposed Approach to Energy Equivalence in the Whole Building Energy Targets Project

PNL-SA-13404 (1986, January)

119
Crawley, D.B., Pacific Northwest Laboratory, Richland, WA

Trends in Building Energy Standards and Guidelines

PNL-SA-13573 (1986, May)

120
Crawley, D.B., Pacific Northwest Laboratory, Richland, WA

Building Systems Integration: Commercial Buildings

PNL-SA-13605 (1986, January)

121
Crawley, D.B., and R.S. Briggs, Pacific Northwest Laboratory, Richland, WA

Envelope Design Implications of ASHRAE Standard 90.1P: A Case Study View

PNL-SA-13144; 28 pp.; CONF-851202; Thermal Performance of the Exterior Envelopes of Buildings - III, Proceedings of the DOE-ORNL-ASHRAE-BTECC Conference, Clearwater Beach, FL, December 2, 1985, 1421 pp. (1985, November)

ASHRAE recently issued a public review draft of Standard 90.1P, Energy Efficient Design of New Non-Residential Buildings and High-Rise Residential Buildings. The revisions proposed in Standard 90.1P are substantially different in structure and content from the existing Standard, especially those sections dealing with building envelope. In this paper, the envelope requirements of Standard 90.1P and their impacts on envelope design features are demonstrated. Several example buildings and locations are used to convey the underlying concepts and nature of the envelope criteria and the implications of those concepts for a variety of envelope attributes.

122
Crawley, D.B., and S.P. Kimsey, Pacific Northwest Laboratory, Richland, WA; Heery Energy Consultants, Inc., Atlanta, GA

Testing Energy Concepts for an Office Building

PNL-SA-13040; 9 pp.; CONF-8503101; Research and Design '85, Proceedings of a Conference, Los Angeles, CA, March 14, 1985 (1985, July)

Energy Design Guidelines for Offices and Schools are being developed by the Tennessee Valley Authority (TVA) for designers in the Tennessee Valley region. TVA also plans to develop similar guidelines for other building types. Development of the Energy Design Guidelines for Offices included an analysis of a generic office building to demonstrate the integration of energy efficiency into the standard design process for office buildings. Glazing, lighting system, and air delivery system alternatives were first tested to determine the best combination for energy efficiency and economic performance, then an additional set of HVAC system options were tested. Based on these energy/economic evaluations, an optimum set of energy concepts was selected for incorporation into the building design. The DOE-2.1A energy analysis program was used to analyze energy performance of the combinations and the cost-effectiveness of the various options was analyzed with an economic evaluation program. Financial criteria of a developer/owner were incorporated to demonstrate typical project economic goals or expectations.

123
Crawley, D.B., and Z.T. Taylor, Pacific Northwest Laboratory, Richland, WA

Comparison of Four Versions of the DOE-2 Energy Analysis Program

PNL-SA-13574; 21 pp.; CONF-860818; Energy Efficiency in Buildings, Proceedings of the American Council for an Energy Efficient Economy Santa Cruz Summer Study, Santa Cruz, CA, August 17, 1986 (1986, April)

In the last five years, four new versions of the DOE-2 building energy simulation program have been released on a regular basis by Lawrence Berkeley Laboratory, DOE-2.1, DOE-2.1A, DOE-2.1B, and the most recent, DOE-2.1C. In this paper, the variation in results from these four versions of DOE-2 are compared and contrasted for several example office buildings in five locations. Variations in annual total and component end-use building energy performance, and the possible reasons for the variances are discussed. Variation in predicted building and plant peak loads are also shown.

124
Crawley, D.B., L.S. Wong, and J.M. Cantrell, Pacific Northwest Laboratory, Richland, WA; Jones, Nall and Davis, Inc., Atlanta, GA

Energy Redesign of the Hirshhorn Museum and Sculpture Garden

PNL-SA-13041; 7 pp.; CONF-8503101; Research and Design '85, Proceedings of a Conference, Los Angeles, CA, March 14, 1985 (1985, July)

A study of energy consumption patterns, energy conservation opportunities, and economic return in the Hirshhorn Museum and Sculpture Garden (HMSG) was conducted in 1982 for the Smithsonian Institution, Office of Design and Construction. This study was but one part of the Smithsonian's program to improve energy efficiency in all their buildings. Existing conditions and operation patterns were determined, opportunities for energy conservation were identified, energy conservation measures were analyzed for energy and economic return, and implementation recommendations were made. Potential savings of 57.2% in energy consumption and 63.4% in annual energy costs were identified, yielding a Savings-to-Investment Ratio (SIR) of 6.9 and a simple payback period of 2 years. This paper describes the study, along with its conclusions and recommendations.

125
Creswick, F.A., Oak Ridge National Laboratory, Oak Ridge, TN

Research on Residential Air-Source Heat Pump Dynamic Losses at ORNL

(1985, September)

126
Creswick, F.A., Oak Ridge National Laboratory, Oak Ridge, TN

The International Energy Agency Heat Pump Center

CONF-841231; Research and Development on Heat Pumps for Space Conditioning Applications, Proceedings of the DOE/ORNL Heat Pump Conference, Washington, DC, December 10, 1984; (5 pp.) (1984)

The Heat Pump Center, its activities, and the potential benefits to U.S. organizations are described briefly.

127
Creswick, F.A., and S.K. Fischer, Oak Ridge National Laboratory, Oak Ridge, TN

Chlorofluorocarbon (CFC) Restrictions: Energy Impacts and Technological Alternatives

CONF-8804100; Research and Development on the Heat Pump for Space Conditioning Applications, Proceedings of the Second DOE/ORNL Heat Pump Conference, Washington, DC, April 17-20, 1988, 225 pp.; (7 pp.) (1988)

Recent international negotiations have resulted in an agreement to restrict the production and use of fully halogenated chlorofluorocarbons. ORNL has conducted a study of technological alternatives to the use of restricted chlorofluorocarbons in building applications and associated potential energy-use impacts. R-123 and R-134a have been identified as promising substitutes for R-11 and R-12. If these substitutes prove to be fully acceptable, energy-use impacts will be nominal. An urgent near-term need exists for information on the engineering properties of these fluids. If the use of substitutes does not prove to be acceptable, the energy-use impact would be an increase of about 1.0 quad/yr, if R-22 is available as a substitute, and about 2.7 quads/yr if not.

128
Crumb, L.W., and A.A. Bohn, Pacific Northwest Laboratory, Richland, WA

Residential and Commercial Buildings Data Book - Second Edition

PNL-5982; 222 pp. (1986, September)

The possession of current and reliable information on building characteristics and energy consumption patterns is a fundamental prerequisite for effective R&D and program planning in the Office of Buildings and Community Systems (BCS). The Residential and Commercial Buildings Data Book is intended to complement other BCS information sources by compiling the most current data on the existing stock of residential and commercial buildings and their energy consumption characteristics. Most of this data is provided in tabular form with accompanying figures used to highlight key points and provides information on forecasts and historical trends for the residential and commercial sectors.

129
D'Ottavio, T.W., and R.N. Dietz, Brookhaven National Laboratory, Upton, NY

Multi-Zone NO2 Reactivity Measurements in a Single Family Home

BNL-37497 (1985, November)

130
Daisey, J.M., Lawrence Berkeley Laboratory, Berkeley, CA

Real-Time Portable Organic Vapor Sampling Systems: Status and Needs

LBL-25808; 18 pp.; CONF-8702158; Proceedings of the American Governmental Industrial Hygienists Conference, Pacific Grove, CA, February 16-18, 1987 (1987, March)

This paper reviews portable and mobile instruments that are commercially available for real-time VOC monitoring in field situations. Portable instruments for detecting explosive gases, such as methane, ethane, butane, etc., are not reviewed here. A wide variety of detection systems have been used in portable VOC monitors including electrochemical and calorimetric detectors, thermal conductivity, flame ionization, photoionization and electron capture detectors, infrared and ultraviolet light spectrometers and quadrupole and ion-trap mass spectrometers. The instruments reviewed here have been grouped by the type of detection system used.

131

Daisey, J.M., and A.T. Hodgson, Lawrence Berkeley Laboratory, Berkeley, CA

Air Cleaner Efficiencies for Removal of Nitrogen Dioxide and Volatile Organic Compounds

LBL-24965; 19 pp.; CONF-880679; Proceedings of the 81st Annual Air Pollution Control Association Meeting, Dallas, TX, June 19-24, 1988 (1988, April)

The objective of this research was to measure the initial effective cleaning rate (ECR) of selected air cleaners for removing NO2 and six representative volatile organic compounds (VOC) from air. Four portable air cleaners, representing three different principles of particle removal and incorporating activated carbon, were investigated. Experiments were conducted in a closed Environmental Chamber using analyte concentrations similar to those reported in residences. Effects of relative humidity, temperature, filter particle loading and saturation of the adsorbents on the ECRs were not investigated in this preliminary study. However, the effect of extended usage was investigated for one air cleaner. Two of the air cleaners were found to be reasonably effective initially in removing NO2 and five of the six VOC. These two devices had relatively high flow rates and the greatest amounts of activated carbon. None of the devices removed dichloromethane, the VOC with the highest vapor pressure. One air cleaner emitted 1,1,1-trichlorethane and formaldehyde. After being used in a residence for 150 hours, the ECRs for the air cleaner which had the highest initial values decreased substantially. This use was only about 15% of the predicted filter lifetime. Conversion of NO2 to NO was also observed for this device but only after it had been used in the residence.

132

Daisey, J.M., J.D. Spengler, and P. Kaarakka, Lawrence Berkeley Laboratory, Berkeley, CA

A Comparison of the Organic Chemical Composition of Indoor Aerosols During Woodburning and Non-Woodburning Periods

DOE/ER/60493-1 (Vol. 1); CONF-870853; Indoor Air '87, Indoor Air Quality and Climate - Volume 1: Volatile Organic Compounds, Combustion Gases, Particles and Fibres, Microbiological Agents, B. Seifert, B., H. Esdorn, M. Fischer, H. Rueden, and J. Wegner, (eds.), Proceedings of the Fourth International Conference, Berlin, Federal Republic of Germany, August 17-21, 1987; (pp. 215-219) (1987)

Concentrations of respirable particulate matter (RSP), extractable organic matter (EOM) and polycyclic aromatic hydrocarbons (PAH) were compared in 7 Wisconsin homes during woodburning and non-woodburning periods. No difference was observed between RSP concentrations during the two periods. Concentrations of EOM, however, were approximately two times higher and of PAH were 2-46 times higher during the periods when the wood stoves were in operation.

133

de Oliveira Loureiro, C., Lawrence Berkeley Laboratory, Berkeley, CA

Simulation of the Steady-State Transport of Radon from Soil into Houses with Basements Under Constant Negative Pressure

LBL-24378; Thesis (Ph.D.); 294 pp. (1987, May)

Normal conditions in a house can produce negative pressure as high as 20 Pa relative to the outside. This underpressure which is a maximum at the base of the house (the basement, for instance), can induce a flow of soil gas into the house through cracks or any other opening in the understructure of the building. Radon (Rn-222), which is produced in the soil and mixed in the soil gas, can then be transported into the house through a complex combination of molecular diffusion and forced convection. In many of the cases where high levels of indoor radon concentrations have been observed in houses, the soil gas has been calculated to be the main source. A theoretical model was developed to simulate this phenomenon, under some specific assumptions. The model simulates: (1) the generation and decay of radon within the soil; (2) its transport throughout the soil due to diffusion and convection induced by the pressure disturbance applied at a crack in the basement; (3) its entrance into the house through the crack; and (4) the resultant indoor radon concentration.

134

DeGrush, D., and W.F. Stoecker, Oak Ridge National Laboratory, Oak Ridge, TN; University of Illinois at Urbana, Urbana, IL

Measurements of Heat-Transfer Coefficients of Nonazeotropic Refrigerant Mixtures Condensing Inside Horizontal Tubes

ORNL/Sub-81/7762/6&01; 129 pp. (1987, November)

Some preliminary observations from previous system tests on a refrigeration facility using a mixture of R-12/R-114 indicated a reduction in condensing heat-transfer coefficients with the mixture in comparison to either constituent operating alone. Further exploration of this phenomenon involved a glass tube condenser constructed previously for observation of the flow regimes during the condensation process. The study, which is documented by this report, was pursed still further with a copper-tube condenser constructed only for the purpose of measuring heat-transfer coefficients and correlating them with the flow regimes previous observed. In tests that duplicated the flow regimes of the earlier work, the previous results were confirmed in that a low heat-transfer coefficient prevails in the early stage of the condenser, for both a single refrigerant and a mixture. It is in the midrange of the condenser that the mixture experiences its greatest reduction in coefficient in comparison to either constituent. Stratified flow prevails in the midrange of the condenser, so that liquid/vapor slip, if it does occur, would be most prominent in this section. Attempts to measure liquid and vapor concentrations to establish the existence of slip were not successful. From an application standpoint, heat-transfer enhancers such as turbulence promoters should be considered for this midsection of the condenser.

135

Dempsey, B., Oak Ridge National Laboratory, Oak Ridge, TN

Mathematical Modeling of Whole Roof System Performance

ORNL/Sub-43122/1 (1986, January)

136

Dempsey, B., Oak Ridge National Laboratory, Oak Ridge, TN

Thermal and Hygric Roof

ORNL/Sub-43122/2 (1986, January)

137

Despotakis, K.A., and A.C. Fisher, Lawrence Berkeley Laboratory, Berkeley, CA

Energy in California Economy: A Computable General Equilibrium Model

LBL-20307 (1985, June)

138

DeVault, R.C., Oak Ridge National Laboratory, Oak Ridge, TN

DOE Absorption Program Overview

CONF-8804100; Research and Development on the Heat Pump for Space Conditioning

Applications, Proceedings of the Second DOE/ORNL Heat Pump Conference, Washington, DC, April 17-20, 1988, 225 pp.; (5 pp.) (1988)

Advanced technologies for gas-fired absorption heat pumps for building space conditioning (heating and/or air conditioning) are being developed with the U.S. Department of Energy support. Single-effect cycle absorption heat pumps for residential application were demonstrated in the 1970s but proved to be uneconomic and were not manufactured. Advanced technology absorption heat pumps with substantially higher efficiencies are now being developed and have the potential to be economically competitive with existing HVAC equipment while saving energy.

139
Diamond, R.C., Lawrence Berkeley Laboratory, Berkeley, CA

Energy Use in Housing for the Elderly: The Effects of Design, Construction, and Occupancy

(1988)

140
Diamond, R.C., Lawrence Berkeley Laboratory, Berkeley, CA

Energy Use Among the Low-Income Elderly: A Closer Look

LBL-17593; 19 pp.; DOE/CE/27460-T17; CONF-840819; Energy Efficiency in Buildings - Doing Better, Setting an Agenda for the Second Decade: Volume F - Perspectives on Individual Behavior, Proceedings of the ACEEE 1984 Summer Study, Santa Cruz, CA, August 14, 1984. American Council for an Energy-Efficient Economy, Washington, DC; (pp. F52-F66) (1984, July)

Detailed examination of eighteen months of utility bills for each unit in the project shows wide variation (on the order of 10-1) in both summer and winter. Because the authors found little correlation between energy use and climate, construction quality, and thermostat settings, he examined additional behavioral and attitudinal data collected from interviews for clues to the large variations observed. Factors affecting the energy used by individual residents as well as by groups of high and low users are presented. Differences in the resident's health and comfort, the level of satisfaction with the heating/cooling system, the degree of understanding and control exercised, attitudes toward conserving, and income and status, all appear to be variables underlying the wide divergence in energy usage.

141
Diamond, R.C., University of California, Berkeley, CA

Case Study of the Determinants of Energy Use in Housing for the Low-Income Elderly

Thesis (Ph.D.); 244 pp. (1986)

The intent of this thesis is to understand the determinants of energy use in residential buildings. A conceptual model is proposed that describes the various determinants and their interrelationships. The model is a very simple one, consisting of two causal relationships. The first is the building sequence of design, construction, and occupancy that provides the physical environment that affects energy use. The second relationship is the linkage between climate, buildings, and occupants that affects energy use. The pivotal element in the model between these two relationships is the occupants. A case study is given to illustrate how the model is used to examine energy use in a housing project for the low-income elderly. Little is known about the energy needs and uses of the elderly; the intent was that by studying this group, specific findings would lead to recommendations for improving their comfort and energy use. Individual elements in the model are examined in detail, and described by the internal and external constraints that influence design, construction, and occupant behavior, and how they, in turn, affect energy use. Because of the broad and interdisciplinary nature of the subject, diverse methods were used for collecting data.

142
Diamond, R.C., and D.J. Dickerhoff, Lawrence Berkeley Laboratory, Berkeley, CA

Guidelines for Air-Leakage Measurements in Single and Multifamily Buildings

LBL-22635 (1988)

143
Diamond, R.C., C.A. Goldman, M.P. Modera, M. Rothkopf, M.H. Sherman, and E. Vine, Lawrence Berkeley Laboratory, Berkeley, CA

Building Energy Retrofit Research: Multifamily Sector - Multiyear Plan FY 1986-FY 1991

LBL-20165; 105 pp. (1985, August)

This document sets out a multiyear plan for research and development activities to accelerate, complement, and support private sector efforts to improve the energy efficiency of the existing multifamily housing stock. The plan was developed after extensive review of ongoing and planned activities in DOE and the private sector, and consideration of the potential for improved energy efficiency of this building stock. The plan will be revised periodically as a result of changes in private sector activity and needs, as well as changes in the planning assumptions.

144
Diamond, R.C., M.P. Modera, and H.E. Feustel, Lawrence Berkeley Laboratory, Berkeley, CA

Ventilation and Occupant Behavior in Two Apartment Buildings

LBL-21862; 23 pp.; CONF-8609226; Occupant Interaction with Ventilation Systems, Proceedings of the Seventh Air Infiltration Centre Conference, Stratford-upon-Avon, United Kingdom, September 29, 1986 (1986, October)

In this paper we approach the subject of ventilation and occupant behavior in multifamily buildings by asking three questions: (1) why and how do occupants interact with ventilation in an apartment building, (2) how does the physical environment (i.e., building characteristics and climate) affect the ventilation in an apartment, and (3) what methods can be used to answer the first two questions. To investigate these and related questions, two apartment buildings in Chicago were monitored during the 1985-1986 heating season. In addition to collecting data on energy consumption, outdoor temperature, wind speed, and indoor apartment temperatures, we conducted diagnostic measurements and occupant surveys in both buildings. The diagnostic tests measured leakage areas of the individual apartments, both through the exterior envelope and to other apartments. The measured leakage areas are used in conjunction with a multizone air flow model to simulate infiltration and internal air flows under different weather conditions. The occupants were questioned about their attitudes and behavior regarding the comfort, air quality, ventilation, and energy use of their apartments. This paper describes each of the research methods utilized, the results of these efforts, and conclusions that can be drawn about ventilation-occupant interactions in these apartment buildings. We found that there was minimal window opening during the winter, widespread use of auxiliary heating to control thermal comfort, and that the simulations show little outside air entry in the top-floor apartments during periods of low wind speeds. The major conclusion of this work is that a multi-disciplinary approach is required to understand or predict occupant-ventilation interactions. Such an approach must take into account the physical characteristics of the building and the climate, as well as the preferences and available options of the occupants.

145
Dickinson, J.B., Lawrence Berkeley Laboratory, Berkeley, CA

A Comparison of Measured versus CIRA Predicted Energy

LBL-18506 (1985)

146

Dickinson, J.B., and H.E. Feustel, Lawrence Berkeley Laboratory, Berkeley, CA

Seasonal Variation in Effective Leakage Area

LBL-19337; 28 pp.; CONF-851202; Thermal Performance of the Exterior Envelopes of Buildings - III, Proceedings of the DOE-ORNL-ASHRAE-BTECC Conference, Clearwater Beach, FL, December 2, 1985, 1421 pp. (1986, January)

Previous research on the seasonal changes in airtightness has been conducted by other researchers on one or two houses in one location. This paper describes air leakage rate measurements using the fan pressurization technique performed monthly over a period of one year in ten occupied houses in three different climates. The purpose of this study is to determine the seasonal variation in effective leakage area in houses in different climates. The three sets of houses included in this study are located in Reno, NV (semi-arid, high desert), Truckee, CA (alpine, mountainous), and the San Francisco Bay Area (temperate, coastal). The results indicate a seasonal variation in effective leakage area in some but not all of the houses; the largest variations are seen in the Truckee houses with effective leakage areas up to 45% higher in the summer as compared to those measured in midwinter.

147

Dikkers, R.D., National Bureau of Standards, Washington, DC

DOE/NBS Forum on Testing and Rating Procedures for Consumer Products

NBSIR-86-3412; PB-87-140588/XAB; 68 pp. (1986, July)

One hundred thirty-four persons participated in a Forum on Testing and Rating Procedures for Consumer Products. The objectives of the forum were: (1) to provide a line of communication, and (2) to assist DOE and NBS in establishing a future agenda for the development and/or revision of testing and rating procedures.

148

Dinan, T.M., Oak Ridge National Laboratory, Oak Ridge, TN

An Analysis of the Impact of Residential Retrofits on Indoor Temperature Choice

ORNL/CON-236; 76 pp. (1987, October)

The objective of this study is to determine whether or not households choose higher winter indoor-temperature levels after their houses have been made more energy efficient. A theoretical model for explaining household temperature choice is developed using a household production function approach. A means model, fixed effects model, and random effects model are used to sort out the observed variation in the pooled cross-section/time-series data set of monitored indoor temperature levels. This analysis reveals that the HRCP residential retrofits resulted in a statistically significant increase in indoor temperature levels. Homes that used electricity as their sole heating fuel had significantly lower levels of takeback, averaging 0.3 deg F.

149

Domanski, P.A., National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Simulation of a Heat Pump Operating with a Non-Azeotropic Mixture

(1985, June)

150

Domanski, P.A., National Bureau of Standards, Washington, DC

Recommended Procedure for Rating and Testing of Variable-Speed Air-Source Unitary Air Conditioners and Heat Pumps

NBSIR-88-3781; PB-88-218227/XAB; 81 pp. (1988, May)

A procedure is presented for testing and rating variable-speed, split residential air conditioners and heat pumps. The procedure is derived in part from existing procedures for single speed and two speed systems where these procedures could be applied, and introduces a new algorithm for representation of variable-speed unit performance in the intermediate speed operation range. Analysis and background which led to the formulation of the procedure are included as well as calculation examples for the cooling and heating mode. The procedure has been prepared for the Department of Energy for consideration in the rule making process.

151
Domanski, P.A., National Bureau of Standards, Washington, DC

Modeling of a Heat Pump Charged With a Non-Azeotropic Refrigerant Mixture: Final Report

PB-86-168267/XAB; NBS/TN-1218; 396 pp. (1986, January)

An analysis of the vapor-compression cycle and the main components of an air-to-air heat pump charged with a binary non-azeotropic mixture was performed for steady-state operation. The general heat-pump simulation model HPBI was formulated, based on independent, analytical models of system components and the logic linking them together. The logic of the program requires an iterative solution of refrigerant pressure and enthalpy balances, and refrigerant mixture and individual-mixture-component mass inventories. The modeling effort emphasis was on the local thermodynamic phenomena described by fundamental heat-transfer equations and equation-of-state relationships among material properties. In the compressor model, several refrigerant locations were identified and the processes taking place between these locations accounted for all significant heat and pressure losses.

152
Domanski, P.A., National Bureau of Standards, Washington, DC

Rating Procedure for Mixed Air-Source Unitary Air Conditioners and Heat Pumps Operating in the Cooling Mode - Revision 1

Report (Rev. 1) (1989, May)

A procedure is presented for determining the cooling performance ratings of air-source unitary air conditioners and heat pumps consisting of a condensing unit and an indoor section which were not tested together as a system. The procedure allows calculation of capacity at the 95 deg F rating point and seasonal energy efficiency ratio, SEER, using as a reference point performance ratings of the condensing unit tested under current DOE procedures in conjunction with a different indoor section. This procedure has been prepared for the Department of Energy for consideration in the rule making process. It is a revised version of the original version of the procedure published in 1986.

153
Domanski, P.A., and D.A. Didion, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

A Sensitivity Study of the Refrigerant Property Uncertainties on the Vapor Compression Cycle

CONF-860945; Heat and Mass Transfer in Refrigeration and Cryogenics, Proceedings of a Meeting, Dubrovnik, Yugoslavia, September 1, 1986. Hemisphere Publishing Company, New York, NY; (pp. 369-380) (1987)

Over the past decade, there has been considerable attention devoted to the performance of refrigeration systems in both simulation model studies and laboratory measurement studies. The accuracy of these studies tacitly depends on knowledge of the various refrigerant thermodynamic and transport properties as well as other flow parameters. The uncertainty with which the property values are known is primarily a function of the state-of-the-art accuracy of the particular property measurement technique. In the case of refrigerant mixtures, there exists very little measured data, and it is therefore necessary to employ mixing rules along with component data. This can increase significantly the uncertainty. For example, vapor density can be evaluated quite well and usually is known within 2% uncertainty; on the other hand, the specific volume of a liquid mixture may have an uncertainty of as much as 100% if it is evaluated by a mixing rule in the neighborhood of critical temperature of the lower boiling component. In the case of evaporative heat transfer coefficients, the actual mixture value has been shown to be as much as 40% lower than that predicted by the ideal mixture weighting factor method.

154
Domanski, P.A., and D.A. Didion, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Cycle Per Cycle Performance

NBSIR-86-3373 (1987, February)

155
Dougall, R.S., G.M. Freedman, R.W. Osborne, and D.L. Mohre, University of Pittsburgh, Pittsburgh, PA; Allegheny Electric Cooperative, Inc., Harrisburg, PA

Monitoring of Residential Groundwater-Source Heat Pumps in the Northeast - Final Report

ORNL/Sub-80/7985/1; 80 pp. (1986, March)

Two rural Pennsylvania single-family residences in a 6000 heating degree-day climate, were retrofitted with add-on groundwater-source heat pumps. Performance data were collected over a two-year period. Data were collected manually and by microcomputer, and included weather, energy use of the heat pump and house, water flow, and temperature. Compared to oil, at 1984 prices, a payback of 4 to 6 years is possible. One unit operated at a COP in heating of nearly 3.0, including an allowance for pumping energy. The COP of the second unit was lower, still better than oil heating but not cost-effective at today's rates. Some initial reliability problems were also encountered with one unit. This emphasizes the need for astute buying and use of comparative ratings on models at conditions consistent with the application. As water-source heat pump performance is affected by water supply temperatures, the rating must be for temperatures similar to groundwater temperatures in the region where the heat pump will be installed, typically 50 to 55 F in Pennsylvania. A substantial quantity of water is required and proper disposal is a consideration. Ponds were used to receive processed water in both test applications. The source groundwater was obtained from wells of more than 50 ft in depth, which are common at rural residences.

156
Dumortier, D., and M.P. Modera, Lawrence Berkeley Laboratory, Berkeley, CA

A Model for Predicting Air Flows Through Two Combustion Appliances Vented by a Single Chimney

LBL-23151; 82 pp. (1987, October)

This report describes the development of a computer program that predicts air flows and temperatures in a chimney venting two combustion appliances. Mass conversion, energy conservation and pressure loss equations are used in conjunction with a thermal model of a chimney to define the system. The resulting system of 18 equations and 18 unknowns is reduced to a single equation, which is then solved by a numerical method. Although the model is generally applicable to venting systems serving two combustion appliances, the case which is examined in detail is that of a steam boiler and domestic hot water heater (DHW) connected to a common masonry chimney in a multifamily building. This installation is typical of those encountered in turn-of-the-century construction in midwestern and northwestern U.S. cities. The computations required to determine the leakage areas of each of the components of the venting system are described, as is a preliminary examination of the model performed by comparing air flow and temperature predictions with measured values for the multifamily boiler, DHW system. The comparison showed good agreement between predictions and experimental results, however a more thorough evaluation of model predictions for systems with and without vent dampers would be appropriate.

157
Ellington, K. (ed.), Lawrence Berkeley

Laboratory, Berkeley, CA

The DOE-2 User News

Quarterly newsletter

This pamphlet provides information on DOE-2, a computer program developed to provide architect/engineers with a public domain tool for fast and economic energy analysis of buildings. The newsletter provides a directory of services, detailed information on courses offered on DOE-2, conferences, and publication listings.

158
Erley, D., J. Vranicar, and J. Getzels, Purdue University, Department of Physics, Lafayette, IN

Energy-Conserving Development Regulations: Monitoring Project

ANL-CNSV-TM-151; 235 pp. (1985)

The project communities' results mirror those of communities with earlier experience in this area. These results can serve as a guide to identifying energy conserving options and associated regulations that are least likely to be controversial. Small scale solar related options - fostering the use of active and passive solar energy systems, protection of solar access, promoting proper solar orientation of buildings - and appropriate landscaping are the most common techniques selected by communities to date for incorporation into development regulations. Fully developed cities, such as Boston, may find that incorporating energy considerations into their standard land-use regulations is not as useful as finding opportunities to incorporate energy conservation into their negotiation process, which is the source of control of major new developments. The communities considered permissive regulations to be more viable than mandatory regulations. Such regulations will encourage energy conserving design on a voluntary basis. Mandatory development regulations have yet to receive wide-spread support from either the project communities or other communities that are engaged in similar efforts. Sample regulations are presented for consideration.

159
Eto, J.H., Lawrence Berkeley Laboratory, Berkeley, CA

On Using Degree-Days to Account for the Effects of Weather on Annual Energy Use in Office Buildings

Energy and Buildings 12:113 (1988)

To better quantify the effects of conservation measures, degree-day-based techniques are commonly used to isolate weather-induced changes in building energy use. A building energy simulation model, is introduced by authors in this paper, which allows one to hold fixed all influences on energy use besides weather, to evaluate several degree-day-based techniques. The evaluation is applied to simulated electricity and natural-gas consumption for two large office building prototypes located in five U.S. climates. The development of degree-day-based, weather-normalization techniques to identify issues for applying the techniques to office buildings are reviewed and the accuracy of the techniques with the simulated data are evaluated. Researchers conclude that, for the two office building prototypes and five U.S. locations examined, most techniques perform reasonably well; accuracy, in predicting annual consumption, is generally better than 10%.

160
Eto, J.H., Lawrence Berkeley Laboratory, Berkeley, CA

Cooling Strategies Based on Indicators of Thermal Storage in Commercial Building Mass

LBL-19912; 17 pp.; CONF-8509126; EEB-BED-85-08; Hot Humid Climate, Proceedings of a Conference, College Station, TX, September 24-26, 1985 (1985, September)

Building thermal mass and multi-day regimes of hot weather are important, yet poorly understood, contributors to cooling energy requirements. This paper develops load-shifting subcooling and pre-cooling equipment operating strategies to address a specific instance of this phenomenon, in which thermal storage by building mass over weekends exacerbates Monday cooling energy requirements. The study relies on computer simulations of energy use for a large, office building prototype in El Paso, TX, using the DOE-2 building energy analysis program. The economic value of the strategies is evaluated with direct reference to utility rate schedules and a crude measure of thermal storage is related to the energy impacts of the strategies. The indicators are based on core zone air temperatures, which are sampled at night when HVAC systems are not in use. The suggestion is made that the results and proposed strategies could be adapted for use by computerized energy management systems to reduce building energy operating costs.

161
Eto, J.H., Lawrence Berkeley Laboratory, Berkeley, CA

Characterizing the Effects of Weather on Commercial Building Energy Use

LBL-19914; 17 pp.; CONF-850817; Building Energy Simulation, Proceedings of a Conference, Seattle, WA, August 21, 1985 (1985, August)

Energy service companies, whose returns are a function of energy savings, have developed energy-normalization methods, based on degree-day measures of weather variation. True tests to determine the adequacy of these methods, however, require careful control of other determinants of building energy use. This paper uses a building energy simulation model to evaluate one of these methods for a large office building in Madison, WI, using twelve years of weather data.

162
Eto, J.H., Lawrence Berkeley Laboratory, Berkeley, CA

A Comparison of Weather Normalization Techniques for Commercial Building Energy Use

LBL-21217; 19 pp.; CONF-851202; Thermal Performance of the Exterior Envelopes of Buildings - III, Proceedings of the DOE-ORNL-ASHRAE-BTECC Conference, Clearwater Beach, FL, December 2, 1985, 1421 pp. (1985, December)

Compilations of measured energy savings have shown that engineering calculations do not always correlate well with actual performance. One important difference between engineering calculations and real world performance is the effect of weather. Energy service companies, whose profits are a function of energy savings, and building energy researchers have developed weather-normalization formulas or techniques. True tests to determine the adequacy of these methods, however, require careful control of other determinants of building energy use. This paper describes results obtained by using a building energy simulation tool to evaluate some of these methods for commercial buildings. Degree-day-based normalization techniques designed to account for the effects of weather on commercial building energy use are identified. The normalization techniques are compared using the results of DOE-2 simulations for two office building prototypes using many years of actual weather data for a single location. It is concluded that, for the prototypes and location examined, the techniques performed reasonably well, and the sophisticated techniques did not perform noticeably better than the simpler ones.

163
Eto, J.H., J. Koomey, J.E. McMahon, and P. Chan, Lawrence Berkeley Laboratory, Berkeley, CA

The Nevada Power Company: Financial Impacts on Utilities of Load Shape Changes Project - Stage IV Summary Report

LBL-21597; 68 pp. (1986, April)

The goal of this Lawrence Berkeley Laboratory (LBL) project is to develop tools and procedures that measure the financial impacts of load shape changes on utility ratepayers and society. In this application, we study the financial impacts of policies that raise the efficiencies of residential appliances. The analysis is based on detailed forecasts of energy use by computer simulation models developed at LBL. These models disaggregate both annual energy use and hourly system electric loads at the end-use level for the residential sector. This detail is essential for calculating production and capacity cost benefits, and tariff-class-specific revenue changes. Avoided costs are calculated independently with a product cost simulation model developed for the Electric Power Research Institute. We are thus able to combine several analytical procedures commonly employed by the industry independent of one another to yield an integrated assessment of the financial impacts of load shape changes. This report is the technical documentation for our case study of the Nevada Power Company (NPC). It provides the interested reader with the underlying assumptions and modeling procedures used to assess the financial impacts of policies that increase the efficiency of residential appliances.

164
Eto, J.H., J.E. McMahon, and P. Chan, Lawrence Berkeley Laboratory, Berkeley, CA

The Pacific Gas and Electric Company Financial Impacts on Utilities of Load Shape Changes Project - Stage II Technical Report

LBL-19751; 48 pp. (1984, June)

The goal of this LBL project is to develop tools and procedures that measure the financial impacts of load shape changes to utility stockholders. In this application, the financial impacts of exogenous policies that raise the efficiencies of residential appliances are studied. The analysis is based on detailed forecasts of energy use by computer simulation models developed at LBL. These models disaggregate both annual energy use and hourly system electric loads at the end-use level. This detail is essential for calculating production and capacity cost benefits, and tariff-class specific revenue changes. Several analytical procedures commonly employed by the industry independent of one another are combined into an integrated assessment of the impacts of load shape changes on utility shareholders.

165
Eto, J.H., J.E. McMahon, and P. Chan, Lawrence Berkeley Laboratory, Berkeley, CA

Virginia Electric and Power Company: Financial Impacts on Utilities of Load Shape Changes Project - Stage III Summary Report

LBL-19752; 26 pp. (1984, December)

Efficiency standards for residential appliances can affect the earnings of electric utilities. The magnitude and direction of the effect depends on the retail rate and marginal cost structure of the individual utility. The goal of this LBL project is to develop tools and procedures to measure this effect for a range of different utilities. We use two end-use models in sequence to estimate the load shape changes induced by residential appliance standards, and a modified formulation of the accountant's statistic for earnings before interest and taxes to calculate the financial impact.

166
Eto, J.H., and G. Powell, Lawrence Berkeley Laboratory, Berkeley, CA

Implications of Office Building Thermal Mass and Multi-Day Temperature Profiles for Cooling Strategies

LBL-19212; 19 pp.; CONF-850810; Proceedings of the National Heat Transfer Conference, Denver, CO, August 4, 1985 (1985, August)

This paper describes a study of the cooling energy requirements that result from thermal storage in building mass, and suggests methods for predicting and controlling its energy cost implications. The study relies on computer simulations of energy use for a large office building prototype in El Paso, TX using the DOE-2 building energy analysis program. Increased Monday cooling energy requirements resulting from the weekend shut-down of HVAC systems are documented. Predictors of energy use and peak demands, which account for thermal storage in building mass, are described. Load-shifting, sub-cooling and pre-cooling equipment operating strategies are evaluated with explicit reference to utility rate schedules.

167

Fagen, T.J., R.R. Young, R.A. Lucheta, and S.E. Veyo, Oak Ridge National Laboratory, Oak Ridge, TN

Engineering Field Evaluation of the Westinghouse/DOE Duel-Stroke Advanced Electric Heat Pump

ORNL/Sub-79/24712/4; 264 pp. (1986, November)

A preprototype advanced electric heat pump with a unique dual-stoke compressor was installed in an occupied residence in Jeannette, PA (near Pittsburgh). Analysis of field performance data indicates a heating performance factor (HSPF) of 8.13 Btu/Wh, and a cooling energy efficiency (SEER) of 8.35 Btu/Wh for the year April 1, 1983 through March 31, 1984. For the year April 1, 1984 through March 31, 1985, the indicated heating season performance factor (HSPF) was 8.51 Btu/Wh and the cooling season energy efficiency ratio (SEER) was 7.89 Btu/Wh. During the first heating season the peak electrical demand at temperatures above 42 F was 4.0 kW. At lower temperatures the demand reached a peak of 18.0 kW at -2 F. During the second heating season modifications to the method of controlling resistance heat and lowering of the upper and lower heating balance points reduced the peak demand to 3.8 kW at temperatures above 38 F. Maximum demand at -10 F was 14.6 kW. Peak electrical demand during cooling operation ranged from 2.1 to 4.6 kW during the first cooling season and 2.2 to 4.2 kW during the second cooling season. The heat pump was considerably oversized for the test house since the observed lower balance point was 8 F whereas 17 F was optimum. Analysis indicates that if properly sized, the system could deliver an HSPF = 8.47 Btu/Wh (30% better than a single capacity heat pump representative of high efficiency units in the market place today), and an SEER = 9.33 Btu/Wh for the weather profile observed at the field test site during the first test year.

168

Fang, J.B., National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

A Computer Program for Calculating Heat Loss From Underground Heat Distribution Systems

NBSIR-86-3367 (1986)

169

Fang, J.B., National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Minimum Life-Cycle Cost Heat Losses for Shallow-Trench Underground Heat Distribution Systems

NBSIR-86-3381; 46 pp. (1986, May)

The rates of heat loss from two underground insulated pipes installed in a shallow trench were calculated using a computer program based on the application of the finite-element method to solution of two-dimensional steady heat-conduction problems. The calculated results of pipe heat loss under a specified ground-temperature condition are summarized for a range of pipe-insulation thickness, different sizes of shallow trench, and various pipe fluid temperatures. Methods of determining the minimum life-cycle cost heat loss and the corresponding economic insulation thickness for shallow-trench heat distribution systems are presented. Life-cycle-costing analysis was performed for two insulated pipes in a concrete trench to determine the cost of construction, annual energy cost associated with pipe heat loss, and yearly operating and maintenance costs.

170

Fang, J.B., and R.A. Grot, National Bureau of Standards, Washington, DC

In Situ Measurements of the Thermal Resistance of Building Envelopes of Office Buildings

ASHRAE Transactions 91(1) (1985, January)

The thermal resistances of various sections of building envelopes in seven office buildings have been determined using heat flux transducers and a portable calorimeter during the winter heating season. This paper presents the results of field tests conducted during the winter heating season in the dynamic thermal performance of the building envelopes of seven office buildings located in different climatic regions.

171
Fang, J.B., R.A. Grot, and H.S. Park, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Assessment of Accuracy of In-Situ Methods for Measuring Building-Envelope Thermal Resistance

NBSIR-86-3328; PB-86-196573/XAB; 28 pp. (1986, March)

A series of field and laboratory tests were conducted to evaluate the accuracy of in-situ thermal resistance measurement techniques. The results of thermal performance evaluations of the exterior walls of six thermal-mass-test houses situated in Gaithersburg, Maryland are presented. In-situ measurements of heat transfer through building envelopes were made with heat flux transfers and portable calorimeters.

172
Feustel, H.E., Lawrence Berkeley Laboratory, Berkeley, CA

Multizone Infiltration Studies at Lawrence Berkeley Laboratory

LBL-17940; 8 pp.; CONF-850804; Heating, Ventilating and Air Conditioning, Proceedings of the World Congress International Exhibition, Copenhagen, Denmark, August 25, 1985 (1986, March)

The simplified infiltration models now used to simulate incoming and outgoing air flows for single-zone structures, such as one-family houses, are not suitable for a high percentage of existing houses, whose floorplans classify them as multizone structures. Multizone infiltration requires extensive and complex information about the flow characteristics and pressure distribution inside the building, and thus has been too difficult to develop and to validate. Our purpose has been to devise a simplified multizone infiltration model. To this end, we have simplified the description of the air-flow distribution in a building by relying on lumped parameters. Further simulation runs are necessary to confirm that these parameters are sufficient for describing infiltration in buildings. This paper describes these parameters and the considerations involved in the development of our multizone infiltration model.

173
Feustel, H.E., Lawrence Berkeley Laboratory, Berkeley, CA

Current Research at Lawrence Berkeley Laboratory on Multizone Infiltration

LBL-18924; Air Filtration Review 6(2) (1985, October)

174
Feustel, H.E., Lawrence Berkeley Laboratory, Berkeley, CA

Development of a Simplified Multizone Infiltration Model

LBL-19095; EEB-EPB-85-14; 24 pp.; CONF-8509198; Proceedings of an AIC Conference, Het Meerdal, Netherlands, September 16, 1985 (1985, November)

Several infiltration models treat the complexity of air flows in multizone buildings, but most of them are written as research tools and are not generally available or user-friendly. Professional engineers and architects are in need of a simplified multizone infiltration model. This paper describes the first step in Lawrence Berkeley Laboratory's development of a multizone infiltration model for calculating the air-flow distribution of a building without using any iteration procedure. To simplify the calculation procedure, buildings are classified into different categories, based on their ratios of permeabilities. These lumped parameters describing the air permeability distribution of a building are used to calculate its overall infiltration/exfiltration rate. The simplified multizone model described is illustrated by a sample calculation.

175
Feustel, H.E., Lawrence Berkeley Laboratory, Berkeley, CA

Ventilation Strategies for Non-Residential Buildings

LBL-26252; 11 pp. (1987, July)

Ventilation in nonresidential buildings in the United States of America has been traditionally provided by means of mechanical ventilation. The ventilation systems have been designed for the maximum load possible for the building and have been used accordingly. The maximum load for a lot of the nonresidential buildings is determined by the amount of ventilation air intake based on the total occupancy rather than by heat transfer through the building's envelope. Tremendous savings are possible by adjusting the outside air flow according to occupancy of the building, especially for buildings with changing rates of occupancy. In most cases, another potential savings can be experienced just by adding heat recovery devices to the existing air handling system. Heat recovery options using a heat pump to heat domestic hot water should be considered for all-electric buildings with a high hot water consumption. Although a number of strategies to save energy have been discovered, none work well for all possible applications in the different climates to be found in the United States. A more detailed investigation applying all the possible strategies for a number of building types in all major climates should follow this study.

176
Feustel, H.E., and V.M. Kendon, Lawrence Berkeley Laboratory, Berkeley, CA

Infiltration Models for Multi-Cellular Structures: A Literature Review

Energy and Buildings 8(1):23 (1985)

Infiltration models are used to stimulate the rates of incoming and outgoing airflows for a building with known leakage under given weather and shielding conditions. Review of the literature reveals the existence of 15 multichambers infiltration models developed between 1966 and 1983.

177
Feustel, H.E., M.P. Modera, and A.H. Rosenfeld, Lawrence Berkeley Laboratory, Berkeley, CA

Ventilation Strategies for Different Climates

LBL-20364; 29 pp.; CONF-8605301; Proceedings of the American Society of Heating, Refrigerating and Air-Conditioning Engineers Conference, Atlanta, GA, May 1, 1986 (1987, March)

Until recently, residential ventilation in the United States has been provided by infiltration. Natural ventilation (ventilation by infiltration) is compared with several mechanical ventilation strategies and examine the overall energy consumption associated with these strategies in different climatic regions in the United States: Natural ventilation, balanced ventilation with an air-to-air heat exchanger, exhaust ventilation without heat recovery, and exhaust ventilation with heat recovery via a heat pump. Two strategies for utilizing for utilizing the heat pump output for domestic hot water are examined. One heat pump strategy employs exhaust fan reversal to provide space cooling whenever possible during the summer months. A modified TRNSYS residential load model incorporating the LBL infiltration model, an algorithm to calculate effective ventilation, and a modified TRNSYS domestic hot water model are used to simulate the energy consumption associated with each strategy. The domestic hot water model is used to determine the useful heat supplied by an exhaust ventilation heat pump as a function of daily hot water demand. The simulations indicate that the choice of ventilation strategy can have a significant impact on energy consumption.

178
Feustel, H.E., and J.L. Scartezzini, Lawrence Berkeley Laboratory, Berkeley, CA

Development and Validation of a Simplified

Multizone Infiltration Model

LBL-23036 (1988)

179
Feustel, H.E., and M.H. Sherman, Lawrence Berkeley Laboratory, Berkeley, CA

A Simplified Model for Predicting Air Flow in Multizone Structures

LBL-22324 (1987, February)

180
Feustel, H.E., C. Zuercher, B. Dickinson, D.T. Grimsrud, and R. Lipschutz, Lawrence Berkeley Laboratory, Berkeley, CA

Temperature- and Wind-Induced Air Flow Patterns in a Staircase: Computers Modelling and Experimental Verification

Energy and Buildings 8(1):105 (1985)

A study of the air flow pattern around the building, tracer gas and fan pressurization measurements on a tall University of California dormitory were performed in order to determine the importance of both wind and stack effect upon infiltration. Measured pressure and tracer gas distributions were compared with those from predictive infiltration computer model for high-rise buildings.

181
Fisher, Z.J., J.M. Fang, A.J. Lyke, and J.R. Krudener, Pacific Northwest Laboratory, Richland, WA

Analysis of Residential, Industrial, and Commercial Sector Responses to Potential Electricity Supply Constraints in the 1990s

PNL-5922; 202 pp. (1986, September)

There is considerable debate over the ability of electric generation capacity to meet the growing needs of the U.S. economy in the 1990s. This study provides new perspective on that debate and examines the possibility of power outages resulting from electricity supply constraints. Previous studies have focused on electricity supply growth, demand growth, and on the linkages between electricity and economic growth. This study assumes the occurrence of electricity supply shortfalls in the 1990s and examines the steps that homeowners, businesses, manufacturers, and other electricity users might take in response to electricity outages.

182
Fisk, W.J., Lawrence Berkeley Laboratory, Berkeley, CA

Research Review: Indoor Air Quality Control Techniques

LBL-21557; 37 pp.; CONF-860446; IAG '86: Managing Indoor Air For Health and Energy Conservation, Proceedings of a Conference, Atlanta, GA, April 20, 1986; (pp. 568-583) (1986, October)

Techniques for controlling the concentration of radon, formaldehyde, and combustion products in the indoor air are reviewed. The most effective techniques, which are generally based on limiting or reducing indoor pollutant source strengths, can decrease indoor pollutant concentrations by a factor of 3 to 10. Unless the initial ventilation rate is unusually low, it is difficult to reduce indoor pollutant concentrations more than approximately 50% by increasing the ventilation rate of an entire building. However, the efficiency of indoor pollutant control by ventilation can be enhanced through the use of local exhaust ventilation near concentrated sources of pollutants, by minimizing short circuiting of air from supply to exhaust when pollutant sources are dispersed and, in some situations, by promoting a displacement flow of air and pollutants toward the exhaust. Active air cleaning is also examined briefly. Filtration and electrostatic air cleaning for removal of particles from the indoor air are the most practical and effective currently available techniques of air cleaning.

183
Fisk, W.J., R.E. Chant, K. Archer, D.

Hekmat, F.J. Offermann, and B.S. Pedersen, Lawrence Berkeley Laboratory, Berkeley, CA

Onset of Freezing in Residential Air-to-Air Heat Exchangers

LBL-18025; 36 pp.; CONF-850123; Proceedings of the Semiannual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Chicago, IL, January, 27-30, 1985; ASHRAE Transactions 91(1B):145 (1984, November)

Mechanical ventilation of residences, with heat recovery in air-to-air heat exchangers, is an increasingly common practice. When this technique of ventilation is used in cold climates, however, freezing can occur in the air-to-air heat exchanger and substantially reduce its performance. A laboratory investigation was conducted to determine the indoor and outdoor environmental conditions that lead to freezing. In a cross-flow, counterflow, and enthalpy-type cross-flow heat exchanger, respectively, freezing was observed when the inlet temperature of the cold airstream was below -7 to -3 deg C, approximately -6 deg C, and -8 to -12 deg C, for a typical range of indoor humidities. These results are in fair agreement with the theoretical predictions presented in this paper and with data from two field studies conducted with similar heat exchangers. Data from a previous laboratory study of a counterflow heat exchanger and tabulated data supplied by ASHRAE, however, indicate that freezing is initiated at significantly lower cold airstream temperatures, particularly when the warm airstream is humid.

184
Fisk, W.J., and D.T. Grimsrud, Lawrence Berkeley Laboratory, Berkeley, CA

Indoor Air Controls

LBL-24346; Environmental Carcinogens Journal (1987)

185
Fisk, W.J., and R.J. Mowris, Lawrence Berkeley Laboratory, Berkeley, CA

The Impacts of Balanced and Exhaust Mechanical Ventilation on Indoor Radon

LBL-23136; 13 pp.; CONF-870853; Indoor Air '87: Indoor Air Quality and Climate, B. Seifert, B., H. Esdorn, M. Fischer, H. Rueden, and J. Wegner, (eds.), Proceedings of the Fourth International Conference, Berlin, Federal Republic of Germany, August 17-21, 1987; (pp. 316-320) (1987, February)

Models for estimating radon entry rates, indoor radon concentrations, and ventilation rates in houses with a basement or a vented crawl-space and ventilated by natural infiltration, mechanical exhaust ventilation, or balanced mechanical ventilation are described. Simulations are performed for a range of soil and housing characteristics using hourly weather data for the heating season in Spokane, WA. For a house with a basement, we show that any ventilation technique should be acceptable when the soil permeability is less than approximately 10(E-12)sq m. However, exhaust ventilation leads to substantially higher indoor radon concentrations than infiltration or balanced ventilation with the same average air exchange rate when the soil permeability is 10(E-10)sq m or greater. For houses with a crawl-space, indoor radon concentrations are lowest with balanced ventilation, intermediate with exhaust ventilation, and highest with infiltration.

186
Fisk, W.J., B.S. Pedersen, D. Hekmat, R.E. Chant, and H. Kaboli, Lawrence Berkeley Laboratory, Berkeley, CA

Formaldehyde and Tracer Gas Transfer Between Airstreams in Enthalpy-Type Air-to-Air Heat Exchangers

LBL-18149; 34 pp.; CONF-850105; Field Measurements of Heat Transfer in Building Envelopes, Proceedings of an American Society of Heating, Refrigerating and Air-Conditioning Engineers Symposium, Chicago, IL, January 27, 1985; ASHRAE Transactions 91(1B):173 (1984, July)

An experimental study is described in which the formaldehyde, tracer gas, and water vapor transfer rates in two enthalpy exchangers were measured. The first exchanger uses a cross-flow fabricated from a treated paper. The core of the second heat exchanger is a rotating heat wheel coated with lithium chloride. To reduce the transfer of gases by air leakage each core was installed in a specially fabricated case. Only 5% to 8% of the two tracer gases and 7% to 15% of the formaldehyde injected into the exhaust airstream was transferred to the supply airstream. Therefore, formaldehyde transfer between airstreams by processes other than air leakage does not seriously compromise the performance of these enthalpy exchangers. Theoretical calculations indicate that the transfer of water vapor between airstreams in enthalpy exchangers can significantly diminish their ability to lower indoor formaldehyde concentrations because of the positive coupling between indoor humidity and the emission rates of formaldehyde from building materials.

187

Fisk, W.J., R.J. Prill, and O. Seppanen, Lawrence Berkeley Laboratory, Berkeley, CA

Commercial Building Ventilation Measurements Using Multiple Tracer Gases

LBL-25614; 18 pp.; AIVC-PROC-9-88-1; CONF-8809127; Effective Ventilation, Proceedings of the Ninth AIVC Conference, Ghent, Belgium, September 12-15, 1988. University of Warwick, Air Infiltration and Ventilation Centre, Coventry, United Kingdom, 1989 (1988, September)

A unique multiple-tracer experimental system has been developed and utilized within commercial buildings to monitor ventilation rates, air exchange efficiency, ages of air (at multiple indoor locations), flow rates of supply and outside air, and percent outside air in supply airstreams. The multiple tracer technique also makes it possible to determine the fractions of air at a monitoring point that entered the building through a particular air handler and by infiltration. To label the incoming air, a distinct tracer gas is injected at a constant rate into each outside air or supply airstream. Cart-mounted gas chromatographs are placed in mechanical rooms and monitor tracer gas concentrations versus time in the major airstreams of the air handlers. Small "local samplers" placed at various indoor locations are utilized to monitor local ages of air. Age distribution theory is applied to determine ages of air; however, the standard methods of applying this theory are modified to process the multiple tracer data. The experimental system, methods of data analysis and the results of studies in both a twelve-story building and a complex of three interconnected two-story office buildings are presented.

188

Florida Solar Energy Center, Cape Canaveral, FL

Thermal Performance - Rangewood Villas: Field Monitoring of Various Conservation Construction Techniques in the Hot-Humid Area

BNL-38134; 86 pp. (1986, June)

Prepared by researchers at Florida Solar Energy Center, this report describes data acquired over a complete year of comprehensive thermal performance monitoring. The construction details of the house and instrumentation system are clearly documented. The project was funded by the Buildings Systems Division of DOE through Brookhaven National Laboratory in an effort to develop the scientific and technical basis for private sector design and construction of more energy efficient buildings in the hot humid regions of the United States. This region is characterized as experiencing 28-32 in. of precipitation annually and 2000 to 3000 cooling degree days. There are ten southeastern states which fall totally or partially within these climatic parameters. Rangewood Villas in Cocoa, Florida is an innovative townhouse project that incorporates several energy efficient construction techniques developed at FSEC, including vent skin roofs and walls utilizing radiant barriers to substantially lower heat gain through radiant transfer of solar energy. The computer simulation model selected as the basis for data acquisition parameters is the Thermal Analysis Research

Program (TARP). Further work is in progress to provide an understanding of the moisture absorption, desorption, and migration process within the building structure and its furnishings.

189
Franke, J.C., F.J. Cronin, J.H. Cable, L.W. Crumb, and J.L. Poirier, Pacific Northwest Laboratory, Richland, WA

Case Study of the Research and Development and Commercialization of Two Energy-Efficient Appliances

PNL-5614 (1985, October)

190
Frohnsdorff, G.J., National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Guide to Selection and Use of Hydraulic Cements

Journal of the American Concrete Institute 82:901 (1985)

191
Fuller, S.K., and R.T. Ruegg, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

The Impact of Energy Pricing and Discount-Rate Policies on Energy Conservation in Federal Buildings - Final Report

NBSIR-85-3262; 61 pp. (1985, November)

The study investigates how energy-conservation projects for federal buildings would be affected by a change in energy pricing and discount-rate policies. It focuses on the choice between marginal-cost prices versus average market prices and a 10% discount rate versus a 7% discount rate. Graphical and numerical comparisons of hypothetical cases in selected geographical areas illustrate the expected impact on selection, design and sizing, and priority of energy-saving projects.

192
Garbesi, K., Lawrence Berkeley Laboratory, Berkeley, CA

Experiments and Modeling of the Soil-Gas Transport of Volatile Organic Compounds into a Residential Basement

LBL-25519; 97 pp. (1988, July)

Research on the entry of radon gas into houses indicates that the pressure-driven entry of soil gas can result in high indoor concentrations of soil-gas contaminants. This paper presents theoretical and laboratory studies of the advective flow of volatile organics compounds (VOC) through soil, and a field investigation of the pressure-driven entry of VOC into a house adjacent to a municipal landfill. The principals of fluid mechanics are used to derive an analytical model of the pressure-driven flow of VOC in soil. The calculation results in the definition of a retardation factor of VOC with respect to the velocity of the bulk soil gas. The retardation equation is then tested in soil-column experiments using sulfur hexafluoride (SF6) and hexafluorobenzene (HFB). The measured retardation is in good agreement with the predicted value. These experiments are used to evaluate the potential of SF6 and HFB as tracer gases for use in a field investigation of the advective flow of soil gas into and near the basement of a house near a landfill and to evaluate the potential of the soil-column apparatus for use in screening the advective mobility of VOC important as landfill gas contaminants. The field study consisted of experiments investigating the influence of basement depressurization on the surrounding soil gas, and quantifying VOC contamination at the site.

193
Gardiner, B.L., Lawrence Berkeley Laboratory, Berkeley, CA

The CAL-BECA Project - Part 1: New California Nonresidential Buildings

LBL-19244; EEB-BED-85-02; 39 pp. (1985, April)

We compiled and analyzed energy consumption data for 26 new California commercial buildings designed to be energy-efficient. Data on building characteristics and design strategies were collected for 29 additional buildings for which energy data were not available. Analysis of these data is part of the CAL-BECA (California Buildings Energy-Use Compilation and analysis) project to increase the measured data on energy savings from conservation measures in California buildings. The buildings, mostly large offices, are operating at a wide range of energy intensities, between 31 and 127 site kBtu/sq ft/yr (86 to 388 kBtu/sq ft/yr, in resource units). Almost half the sample are operating at levels between 60 and 80 site kBtu/sq ft/yr. Daylighting and shading strategies are the most common energy-saving design features in this sample. We present the results of the data base project and discuss limitations of the data, which restrict evaluations of energy performance and prevent correlation of specific design strategies with energy performance.

194
Gardiner, B.L., and M.A. Piette, Lawrence Berkeley Laboratory, Berkeley, CA

Measured Results of Energy Conservation Retrofits in Nonresidential Buildings: Interpreting Metered Data

LBL-19243; CONF-850606; Proceedings of the Semiannual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Honolulu, HI, June 23-26, 1985; ASHRAE Transactions 91(2B):1488-1500 (1985)

Most estimates of energy savings and cost-effectiveness of building energy conservation measures are based on engineering calculations or computer simulations. A compilation of utility billing data in occupied buildings is an important compliment to these estimates and provides feedback on building owners and operators on how well conservation retrofits work in practice. We have compiled energy consumption data on over 300 nonresidential buildings that have been retrofitted with energy conservation measures. For the 94% of the buildings in our sample that saved site energy, median savings were 31 kBtu/sq ft/year (350 MJ/sq m/year). In this paper, the authors discuss the benefits and limitations of using whole-building metered data to evaluate energy savings attributable to conservation measures. Submetered energy consumption data are scarce; they present examples and discuss the additional benefits such data can provide to the building operator in assessing the impacts of specific retrofit measures.

195
Gardiner, B.L., M.A. Piette, A.K. Meier, C.B. Smith, T. Davis, and P.W. Turnbull, Lawrence Berkeley Laboratory, Berkeley, CA

Measured Energy Performance of New Retrofitted Commercial Buildings

LBL-19389; CONF-850583; Great PG and E Energy Expo '85, Meeting Energy Challenges - Volume 2, Proceedings of the Second Pacific Gas and Electric (PG and E) Energy Exposition, Oakland, CA, May 21, 1985. Pergamon Books, Inc., Elmsford, NY; (pp. 259-268) (1985)

Due to the diversity and complexity of the commercial building stock, understanding of commercial building energy performance is limited. Measured energy consumption data for commercial buildings are needed to complement engineering calculations and computer simulations of the energy savings and cost-effectiveness of energy conservation measures. To address this need, the Buildings Energy Data Group at Lawrence Berkeley Laboratory has compiled measured energy use data for over 400 new and retrofitted commercial buildings. Most of the new buildings in our data base are operating at energy consumption levels well below stock average. The retrofitted buildings show an average 25 percent reduction in pre-retrofit site energy use.

196
Gettings, M.B., L.N. McCold, and J.A. Schlegel, Oak Ridge National Laboratory, Oak Ridge, TN

Field Test Evaluation of Conservation Retrofits of Low-Income Single-Family

Buildings in Wisconsin: Blower-Door-Directed Infiltration Reduction Procedure: Field Test Implementation and Results

ORNL/CON-228/P5; 71 pp. (1988, June)

A blower-door-directed infiltration retrofit procedure was field tested on 18 homes in south central Wisconsin. The procedure, developed by the Wisconsin Energy Conservation Corporation, includes recommended retrofit techniques as performed on a house. A recommended expenditure level and target air leakage reduction, in air changes per hour at 50 pascal (ACH50), are determined from the initial leakage rate measured. The average cost of retrofits per house was reduced by a factor of four compared with previous programs.

197
Gillette, G., and M.A. Brown, Oak Ridge National Laboratory, Oak Ridge, TN

Occupant Evaluation of Commercial Office Lighting: Volume I - Methodology and Bibliography

ORNL/TM-10264/V1 (1987, November)

This report documents the forms and procedures developed for a post-occupancy evaluation of office lighting environments. It is the first in a series of four reports. The central aim of the larger project is to explore possible causal factors that are associated with successful lighting design, with particular interest in the relationship between the connected lighting power load and subjective measures of lighting quality. A post-occupancy evaluation procedure was used as the strategy for obtaining the desired data. The procedure involved collecting several different types of data: (1) direct measures of the physical environment, including spatial luminances, illuminances, and contrast conditions; (2) indirect measures such as the amount of space provided for each work station and the connected lighting power load; (3) occupant responses to lighting and other factors of the work station; and (4) a limited number of expert ratings of the lighting conditions. Data from thirteen buildings and 1,217 work stations were collected. These data were built into a database allowing lighting quality to be quantified and explained.

198
Gillette, G., and M.A. Brown, Oak Ridge National Laboratory, Oak Ridge, TN

Occupant Evaluation of Commercial Office Lighting: Volume III - Data Archive and Database Management System

ORNL/TM-10264/V3 (1987, August)

This report documents a database of measured lighting environmental data. The database contains four different types of data on more than 1000 occupied work stations: (1) subjective data on attitudes and ratings of selected lighting and other characteristics; (2) photometric and other direct environmental data, including illuminances, luminances, and contrast conditions; (3) indirect environmental measures obtained from the architectural drawings and the work station photographs: and (4) descriptive characteristics of the occupants. The work stations were sampled from thirteen office buildings located in various cities in the United States. In the database, each record contains data on a single work station with its individual fields comprising characteristics of that work station and its occupant. The relational database runs on an IBM or IBM compatible personal computer using commercially available software. As a supplement to the database, an independent ASCII-8 bit data file is available.

199
Girman, J.R., J.R. Allen, and A.Y. Lee, Lawrence Berkeley Laboratory, Berkeley, CA

A Passive Sampler for Water Vapor

LBL-17599; 13 pp.; CONF-840803; Indoor Air Quality and Climate, Proceedings of the Third International Conference, Stockholm, Sweden, August 20, 1984; Environment International 12:461-465 (1984, February)

In this preliminary study, we report on improvements made to a passive sampler for water vapor and on the results of tests to determine its suitability for studies of indoor air quality. Tests completed demonstrated precision, accuracy, linear response with exposure, sensitivity and capacity sufficient for use in large scale studies to determine absolute humidities inexpensively.

200

Girman, J.R., et al., Lawrence Berkeley Laboratory, Berkeley, CA

Considerations in Evaluating Emissions from Consumer Products

LBL-19915 (1985, June)

201

Girman, J.R., and A.T. Hodgson, Lawrence Berkeley Laboratory, Berkeley, CA

Source Characterization and Personal Exposure to Methylene Chloride from Consumer Products

LBL-20227; 75 pp.; CONF-860606; Proceedings of the Annual Air Pollution Control Association Meeting and Exhibition, Minneapolis, MN, June 22, 1986 (1986, March)

A recently completed bioassay, which found methylene chloride (CH2Cl2) to be an animal carcinogen, has increased the concern about consumer exposure to this chemical. To provide information on exposures sufficient to conduct a health risk assessment, CH2Cl2 source strengths and personal exposures were characterized in a room-size (20 cu m) environmental chamber for representative applications of several paint removers and aerosol finishes as examples of the two major types of consumer products containing CH2Cl2. Exposure models based upon the concentration models were also developed and then evaluated by comparing theoretical and measured exposures for the experiments. The exposure models appeared to have sufficient accuracy and precision for use in assessment of consumer health risk from the use of consumer products containing CH2Cl2.

202

Girman, J.R., A.T. Hodgson, A.S. Newton, and A.W. Winkes, Lawrence Berkeley Laboratory, Berkeley, CA

Volatile Organic Emissions from Adhesives with Indoor Applications

LBL-17594; 12 pp.; CONF-840803; Indoor Air Quality and Climate, Proceedings of the Third International Conference, Stockholm, Sweden, August 20, 1984; Environment International 12:317-322 (1984, February)

Studies have shown that volatile organic compounds (VOC) emitted from building materials are a potentially important source of indoor air pollution. In this study, we investigated emissions of VOC from both solvent- and water-based adhesives. Adhesives were applied to an inert substrate and dried for at least a week. VOC were cryogenically trapped and identified by GC-MS or sorbent trapped, solvent extracted, and quantified by GC-FID. Among the compounds emitted by adhesives were toluene, styrene, and a variety of normal, branched, and cyclic alkanes. The measured emission rates ranged from below the limit of detection for some adhesives to a total alkane emission rate of over 700 um g(E-1)/hr(E-1) for a water-based adhesive. A simple, well-mixed tank model was used to assess the potential impacts of the adhesives studied and to demonstrate that adhesives can be significant sources of VOC.

203

Glicksman, L.R., A.G. Ostrogorsky, and S. Chiappetta, Massachusetts Institute of Technology, Cambridge, MA

Effective Conductivity of Aging Polyurethane Foam

ORNL/Sub-84/9009/1; 64 pp. (1986, March)

Rigid polyurethane foams with closed cells are used for insulation. Low conductivity refrigerant vapor is contained in the cells of fresh foam giving them superior thermal properties. The aging effect, i.e. the degradation of foam thermal properties due to diffusion of air into the foam, is a major drawback of the polyurethane foams. Some foams exhibit as much as a 50% increase of the overall thermal conductivity over one or two years. An experimental technique was developed to measure the permeability of the cell walls to air components. Cell walls obtained from large bubbles were used as samples. The large bubbles are found on the surface of free rise foam. Once cell wall permeability and cell geometry are known, the foam effective diffusion coefficient can be computed from a model developed earlier and the simple laboratory tests were developed to measure the effectiveness of the diffusion barriers.

204
Goeltz, R., and E.A. Hirst, Oak Ridge National Laboratory, Oak Ridge, TN

Residential Retrofit Measures in the Hood River Conservation Project: Recommendations, Installations, and Barriers

ORNL/CON-208; 45 pp. (1986, June)

The Hood River Conservation Project (HRCP) is a major residential retrofit demonstration project. The Project was conducted in the community of Hood River, Oregon, at an estimated cost $21 million, and will last for three years (mid-1983 through 1986). The project sought to install as many cost-effective retrofit measures in as many electrically-heated homes in Hood River as possible. HRCP planning, implementation, and analysis are guided by a Research Advisory Group, whose members represent the major participants in the project. This report documents the extent to which measures included in the Project were recommended and installed in participant homes and also examines the reasons for noninstallation of measures, the barriers between potential and practice.

205
Goldman, C.A., Lawrence Berkeley Laboratory, Berkeley, CA

Measured Energy Savings from Residential Retrofits: Updated Results from the BECA-B Project

LBL-17926; Energy and Buildings 8(2):137-155 (1985, May)

This study summarizes measured data on energy savings from conservation retrofits in existing residential buildings. The authors have compiled building performance data on approximately 115 retrofit projects (almost twice the size of the initial study) put into four general categories: utility-sponsored conservation programs, low-income weatherization programs, research studies, and multifamily buildings. The sample size for each project varies widely, ranging from individual buildings to 33,000 homes. Retrofits to the building shell, principally insulation of exterior surfaces, window treatments, and infiltration reduction measures, are the most popular, although data on various heating system retrofits are now available. The average retrofit investment, per unit in multifamily buildings is approximately $695, far lower than the average of $1350 spent in singlefamily residences. The median annual space heat savings in the four categories range from 15 to 38 GJ. Savings achieved are typically 20%-30% of pre-retrofit space heating energy use although large variations are observed both in energy savings and in costs per unit of energy saved. Even given the wide range in savings, most retrofit projects are cost-effective.

206
Goldman, C.A., Lawrence Berkeley Laboratory, Berkeley, CA

Measured Results of Energy Conservation Retrofits in Residential Buildings

LBL-20950; 25 pp.; CONF-860106; Proceedings of the Semiannual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, San Francisco, CA, January 19, 1986 (1985, July)

This study summarizes measured data on energy savings from conservation retrofits in existing residential buildings to the building shell, principally insulation of exterior surfaces, window treatments, and infiltration-reduction measures, are the most popular, although data on various heating system retrofits are now available. The average retrofit investment per unit in multi-family buildings is approximately $700, far lower than the average of $1350 spent in single-family residences. Savings achieved are typically 20% to 30% of pre-retrofit space heating energy use, although large variations are observed both in energy, savings and in costs per unit of energy saved. Particularly cost-effective retrofit strategies are identified based on measured energy use data. Predicted versus actual savings are also compared for groups of homes in 24 retrofit projects.

207

Goldman, C.A., K.M. Greeley, and J.P. Harus, Lawrence Berkeley Laboratory, Berkeley, CA

Retrofit Experience in U.S. Multifamily Buildings: Energy Savings, Costs, and Economics

Energy 13(11):797 (1988)

Authors present the energy savings and costs of conservation measures in U.S. multifamily buildings based on an analysis of measured data from buildings data base of over 25,000 dwelling units. Median energy savings were 1450 kW/hr/unit in electric-heat buildings and 14 MBtu/unit in fuel-heat buildings, or approximately 14-16% of pre-retrofit consumption. Researchers found that differences in pre-retrofit usage, size of investment, and choice of retrofit strategy were particularly influential in explaining the variation in energy savings among buildings. Same observations were: Retrofit costs were typically much lower in fuel-heat buildings than in electric-heat buildings ($370/unit versus $1600/unit). Median payback time in fuel-heat buildings was 6 yr; paybacks were typically 20-25 yr in electric-heat buildings where the emphasis was on costly shell improvements. Comparisons of pre-retrofit predictions with actual savings showed fairly good agreement on average, in five out of seven programs, although the variance for individual buildings was often quite large. Extrapolating these measured retrofit results to the U.S. multifamily stock suggests opportunities for saving 0.2-0.5 quads/yr (resource energy), which represent 10-22% of current consumption.

208

Goldman, C.A., and R.L. Ritschard, Lawrence Berkeley Laboratory, Berkeley, CA

Energy Conservation in Public Housing: A Case Study of the San Francisco Housing Authority

Energy and Buildings 9(1&2):89 (1986)

In 1982, the San Francisco Housing Authority began trying to reduce rapidly increasing energy expenses by installing attic insulation, exterior door weather stripping, and low-flow showerheads in the buildings that it manages. The conservation measures were financed by the local utility's zero-interest loan program. In this study, optimal approaches for selection, marketing, and financing of energy conservation retrofits in public housing is discussed.

209

Graves, R.S., and D.W. Yarbrough, Oak Ridge National Laboratory, Oak Ridge, TN

An Experimental Study of Stabilized Cellulosic Insulation Installed in Four Attic Sections of Manufactured Homes

ORNL/TM-10775 (1988)

The effect of vibrations due to manufacturing and over-the-road transport on the thickness, density, and calculated thermal assistance (R-valve) of stabilized cellulosic insulation installed in four manufactured home units has been determined. Stabilized cellulosic insulation is produced by adding water at the time of installation to dry loose-fuel cellulosic insulation containing adhesive. Insulation thickness and density measurements are presented and reduction in R-value is calculated.

210

Graves, R.S., and D.W. Yarbrough, Oak Ridge National Laboratory, Oak Ridge, TN

Thickness, Densities, and Calculated Thermal Manufactured House

ORNL/TM-9927 (1986, February)

The effect of vibrations due to manufacturing and transport on the thickness, density, and calculated thermal resistance (R-value) of loose-fill rock wool insulation installed in two manufactured home units has been determined. Thickness and density measurements on blown attic insulation were made after installation, at the end of the manufacturing process, and after the units were towed 265 miles. These measurements were used to calculate R-values for the attic insulation. The end sections of the two units showed an overall insulation thickness decrease of about 16% and an average R-value change from 31.2 to 28.8 sq ft/hr/F/Btu. An estimated R-value greater than 30 sq ft/hr/F/Btu resulted from averaging the end and middle sections of the two units. The effect of reduced thickness along the edges of the attic space was not included in the estimate.

211
Graves, R.S., D.W. Yarbrough, and D.L. McElroy

Apparent Thermal Conductivity Measurements by an Upgraded Technique

(1985, October)

212
Greenberg, J., B. Reeder, and S. Silberstein, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Review of Energy Use Factors for Selected Household Appliances

NBSIR-85-3220; PB-86-108198/XAB; 87 pp. (1985)

Selective parametric values for household appliances were reviewed. Analysis of current data collected and comments and recommendations are included. Parameters reviewed were; for water heaters, inlet water temperatures; outlet water temperature, ambient air temperature, and hot water usage; for furnaces, outside design temperature and average and annual heating hours; and for room and central air conditioners, yearly hours of use.

213
Griggs, E.I., Tennessee Technological University, Cookeville, TN

The Impact of Surface Reflectance on the Thermal Performance of Roofs: An Experimental Study

CONF-880627; Proceedings of the Annual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Ottawa, Canada, June 25-29, 1988; (32 pp.) (1988)

Thermal effects of black versus white membranes on an insulated low sloped roof were studied over an 18 month period. Half of the insulated roof tests panel's 4 ft by 8 ft surface was covered with black polyisobutylene membrane. Seasonal distinctions in measured data between black and white membranes were recorded daily.

214
Griggs, E.I., and G.E. Courville, Oak Ridge National Laboratory, Oak Ridge, TN

Changes in Building Heating and Cooling Requirements Due to a Reduction in the Roof's Solar Absorptance

(1985, December)

Sunlit surfaces of buildings experience higher temperatures during hours of solar exposure than those experienced by unexposed surfaces. The solar radiation incident on building exterior surfaces may, in turn, affect the heating and cooling loads imposed on the building's HVAC system. An increase in surface temperature due to insulation increases heat gain during the summer and reduces heating loss during the winter. Since this is a counteracting influence with regard to energy usage, questions arise as to how annual HVAC energy requirements are changed when a surface's radiative properties are altered. The study reported here focused specifically on changes in heating and cooling loads when the roof's solar absorptance was reduced from 0.8 to 0.3. Calculations were made using DOE-2.1B for two different buildings at twenty different cities. A third building type was examined for five of the locations. The paper presents the calculated load changes in the form of bar graphs. The magnitude of the load changes is shown to be significantly influenced by the convective coefficient. For locations of high solar intensity and low heating requirements, use of roofs with low solar absorptance can represent meaningful energy savings.

215
Grimsrud, D.T., Lawrence Berkeley Laboratory, Berkeley, CA

Characterization of Sources and Emissions in Field Studies

LBL-22478; Atmospheric Environment 21(2):359-360 (1987)

216
Grimsrud, D.T., Lawrence Berkeley Laboratory, Berkeley, CA

Identification of Indoor Air Quality Issues - Final Report

Paper No. 008.1-87.7 (1986)

217
Grimsrud, D.T., J.T. Brown, W.J. Fisk, and J.R. Girman, Lawrence Berkeley Laboratory, Berkeley, CA

The Indoor Environment of Commercial Buildings: A Review

LBL-24347; 130 pp. (1987, August)

This report reviews current information that has been gathered recently about the indoor environment in commercial buildings. Basic background information about air pollutants, their concentrations and control presented. Special attention is given to a discussion of ventilation systems since these systems provide the basic pollutant control function for the building. The contribution of pollutants, malfunctioning ventilation and other causes to building complaints is a recuring theme of the treatment.

218
Grimsrud, D.T., et al., Lawrence Berkeley Laboratory, Berkeley, CA

Effects of House Weatherization on Indoor Air Quality

LBL-23138; DOE/ER/60493-1 (Vol. 2); CONF-870853; Indoor Air '87, Indoor Air Quality and Climate - Volume 2: Environmental Tobacco Smoke, Multicomponent Studies, Radon, Sick Buildings, Odors and Irritants, Hyperreactivities and Allergies, B. Seifert, B., H. Esdorn, M. Fischer, H. Rueden, and J. Wegner, (eds.), Proceedings of the Fourth International Conference, Berlin, Federal Republic of Germany, August 17-21, 1987; (p. 208) (1987)

Current information about the indoor environment in commercial buildings is reviewed. Basic background information about air pollutants, their concentrations and control presented. Special attention is given to a discussion of ventilation systems since these systems provide the basic pollutant control function for the building. The contribution of pollutants, malfunctioning ventilation and other causes to building complaints is a recurring theme of the treatment.

219
Grimsrud, D.T., R.F. Szydlowski, and B.H. Turk, Lawrence Berkeley Laboratory, Berkeley, CA

Field Study of Exhaust Fans for Mitigating Indoor Air Quality Programs - Final Report

LBL-22281; 104 pp. (1986, September)

As a result of a concern about the impact of the programs on air quality in the buildings, BPA initiated several indoor air quality studies to examine this issue. This report describes results from one of the first of a series of field studies undertaken by the Indoor Environment Program of Lawrence Berkeley Laboratory (LBL) for BPA. Residential ventilation in the United States housing stock is provided primarily by infiltration, the natural leakage of outdoor air into a building through cracks and holes in the building shell. Since ventilation is the dominant mechanism for control of indoor pollutant concentrations, low infiltration rates caused fluctuations in weather conditions may lead to high indoor pollutant concentrations. The study also examined effects of small continuously-operating exhaust fan on pollutant concentrations and energy use in residences. The report is divided into seven chapters that describe the study's design, measurement protocol, results, and interpretation. Results are summarized in terms of the objectives of the study.

220
Grimsrud, D.T., B.H. Turk, J. Harrison, and R.J. Prill, Lawrence Berkeley Laboratory, Berkeley, CA

A Comparison of Indoor Air Quality in Pacific Northwest Existing and New Energy-Efficient Homes

Proceedings of the 79th Annual Air Pollution Control Association Meeting, Minneapolis, MN; Paper No. 86-16.3 (1986)

221
Grossman, G., and E. Michelson, Oak Ridge National Laboratory, Oak Ridge, TN

Absorption Heat Pump Simulation and Studies: A Modular Computer Simulation of Absorption Systems - Final Report

ORNL/Sub-83/43337/2; 83 pp. (1986, April)

A computer simulation program for absorption systems has been developed in a flexible and modular form, which makes it possible to simulate various configurations with different working fluids. The user supplies input containing information about given flow rates and temperatures, as well as characteristics of the various subunits of the system. In addition, the user must convey to the computer an image of the cycle in question. The program calculates the temperature, composition, flow rate, and pressure at each state point of the system and the heat quantities at each unit, from which the coefficient of performance may be determined. The program has been tested on single- and double-stage absorption heat pumps and heat transformers with lithium bromide-water and water-ammonia as the working fluids. Results have been compared with experimental data from tests of a lithium bromide-water heat transformer, giving good agreement.

222
Grot, R.A., and J. Axley, National Bureau of Standards, Washington, DC

The Development of Models for the Prediction of Indoor Air Quality in Buildings

Ventilation Technology-Research and Application, Proceedings of the Eighth AIVC Conference, Uberlingen, Federal Republic of Germany, September 21-24, 1987 (1987, September)

The National Bureau of Standards has undertaken a research effort to develop a general indoor air quality simulation program for buildings. At present there exists three computer programs which can be used to analyze interzonal air movements in multizoned buildings and predict the level of contaminants due to a wide variety of contaminants. This paper will introduce the reader to the scientific and mathematical basis of the models, the preparation of building input data for these programs, and the use of the models for both residential and commercial buildings. Greater detail may be found in reference.

223
Grot, R.A., M.P. Modera, J.B. Fang, and H.S. Park, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Instrumentation for the In-Situ Measurement of Building Envelopes

CONF-850606; Proceedings of the Semiannual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Honolulu, HI, June 23-26, 1985; ASHRAE Transactions 91(2B):1080-1100 (1985)

This paper discusses the types of instrumentation that can be used for the in-situ measurement of the thermal resistance of building components. Four types of instrumentation are described: noncontact spot radiometers, contact heat flow transducers, portable calorimeters, and a type of portable guarded hot plate device developed by Lawrence Berkeley Laboratories, called an envelope thermal testing unit. A brief description of each device is given along with a description of how the device is used to measure in-situ thermal properties of building components. A theoretical justification of the use of long-term averaging of the heat flow and temperature data for estimating the thermal resistance is also presented. The accuracy of each in-situ measurement method is accessed.

224
Grot, R.A., A.K. Persily, Y.M. Chang, J.B. Fang, and S.F. Weber, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Evaluation of the Thermal Integrity of the Building Envelopes of Eight Federal Office Buildings

NBSIR-85-3147; PB-86-135274/XAB; 199 pp. (1985, September)

Diagnostic test methods were applied to eight federal office buildings in order to assess the applicability of these measurement methods for determining the thermal integrity of the building envelope. The eight federal office buildings were located in Anchorage, AK; Ann Arbor, MI; Columbia, SC; Fayetteville, AR; Huron, SD; Norfolk, VA; Pittsfield, MA and Springfield, MA.

225
Guerin, M.R., Oak Ridge National Laboratory, Oak Ridge, TN

Formation and General Characteristics of Environmental Tobacco Smoke

CONF-8809129; Combustion Processes and the Quality of the Indoor Environment, Proceedings of the APCA Specialty Conference, Niagara Falls, NY, September 27, 1988; (12 pp.) (1988)

The primary source of environmental tobacco smoke is the smoke released directly from the tips of cigarettes between puffs: the sidestream smoke. Sidestream smoke is formed under different conditions than is mainstream smoke. It is enriched in alkaline constituents, contains greater quantities of vapor phase water, exhibits a smaller particle size, and is less affected by smoking conditions and cigarette design. Upon dilution in ambient air, particle size decreases due to evaporation, thus redistributing many constituents from the particle phase to the vapor phase. Commonly found concentrations of ETS particulates matter, nicotine, and carbon monoxide in indoor environments are 50-200 um g/cu m, and 2-6 ppm, respectively.

226
Haberl, J.S., M. McDonald, and A. Eden, University of Colorado, Boulder, CO

An Overview of 3-D Graphical Analysis Using DOE-2 Hourly Simulation Data

CONF-880128; Proceedings of the American Society of Heating, Refrigerating and Air-Conditioning Engineers Winter Meeting, Dallas, TX, January 30-February 3, 1988. American Society of Heating, Refrigerating and Air-Conditioning, Atlanta, GA; (16 pp.) (1988)

An overview of 3-D graphical approach for improving the potential of building energy analyses produces 3-D annual profiles for hourly data generated by DOE-2 simulations using a statistical plotting package for specific quantities. These profiles provide the user with the opportunity to check simulation results, potential problems with user input, provide graphs for customers, and visualize interactions in simulations.

227
Hamblem, S.E., and F.W. Payne, Oak Ridge National Laboratory, Oak Ridge, TN

Analysis of Air-Conditioning Controls for Building 4500 South - Oak Ridge National Laboratory

Integration of Efficient Design Technologies. Fairmont Press, Inc.; (p. 341) (1988)

Reports of unstable zone temperatures throughout Building 4500N of Oak Ridge National Laboratory resulted in a study of control systems of the four main air-conditioning units that service the building. The purpose of the study was to determine the source of the problem and to make recommendations for correcting the situation.

228
Hamblin, D.M., B. Thomas, R.J. Maddigan, C.W. Forman, L.J. Bibo, and K.M. McKeehan, Oak Ridge National Laboratory, Oak Ridge, TN; Economic System Analysis, Inc., Oak Ridge, TN; Bonneville Power Administration, Portland, OR

The ORNL Residential Reference House Energy Demand Model (ORNL-RRHED): Volume 1 - Overview and Report Summary

ORNL/CON-177/V1; 44 pp. (1986, February)

This report describes the use and structure of the ORNL Residential Reference House Energy Demand Model (RRHED). RRHED is a computer-based engineering-economic end-use simulation model which forecasts energy demand based on a detailed evaluation of how households use energy for particular appliances. The report is organized into four volumes. The first volume provides an overview of the modeling approach and gives a short summary of the material presented in the other three volumes; Volume 2 presents a user reference guide which provides the details necessary for users of the model to run the code and make changes to fit their particular application; Volume 3 presents the basic theoretical rationale for the RRHED model structure; and the last volume reports on the application of the model to the analysis of two different kinds of issues. These issues include the examination of conservation policy impacts and the forecasting of electricity demand in a need for power assessment. The report also provides the reader with background information on end-use modeling with an introduction to how the RRHED model works and highlights details needed by a user of the model to understand not only the theory behind the model specification, but also the structure of the code.

229
Hans, B.J., and D.W. Yarbrough, Oak Ridge National Laboratory, Oak Ridge, TN; Tennessee Technological University, Cookeville, TN

Thermal Resistance of Wall Cavities Containing Reflective Insulation

ORNL/Sub-7715/6; 129 pp. (1988, August)

The thermal resistance (R) for standard wall cavities containing reflective insulation has been determined by numerically solving the Navier-Stokes and macroscopic energy balance equations for temperature and velocity distributions using the Boussinesq approximation. The numerical solutions were used to determine Nusselt numbers (Nu) for rectangular air-filled cavities with aspect ratios (A), height divided by thickness ranging from 4 to 240, Prandti number equal to 0.7, and specific heat ratio equal to 1.4. The range of A values for which results were obtained includes values present in reflective insulation assemblies.

230
Hares, J.A., and A.R. Greil, Bonneville Power Administration, Portland, OR

A Study of the Filling of Wall Cavities with Retrofit Wall Insulation

DOE/BP/1017; 20 pp. (1988, August)

The Pacific Northwest Power Marketing Agency and the Bonneville Power Administration (BPA), conducted a retrofit wall insulation study to determine the effects of various obstructions within a wall cavity where voids are likely to occur, preferred filling methods and materials types. The insulation test structure was composed of four 8-ft X 12-ft walls, and was built using standard construction practices. The inside walls were clear plastic glazing, instead of gypsum board, to enable viewing of the filling process. A total of eight tests were performed: four cellulose, two rockwool, and two fiberglass. One- and two-hole filling methods were also observed.

231
Harris, J.P., Lawrence Berkeley Laboratory, Berkeley, CA

The BECA Data Base on Energy-Efficient Buildings: Selected Results and Policy Implications

LBL-19347 (1985, July)

Measured energy performance data drawn from the "BECA" data base at LBL on several hundred new and retrofitted residences are summarized. The two-way relationship between occupant behavior and the physical characteristics and energy performance of residential buildings are explored. A more detailed, empirical understanding of both physical and occupancy variables is needed to help explain the observed variance in energy performance among physically similar houses, as well as the variance between performance predictions and actual measurements according to authors. The evaluation of "occupant effects" raised questions not only of insufficient data, but of inadequate definition of the outputs resulting from energy use: occupant comfort, well-being, and other "building services." Energy efficiency is defined not as reduced consumption, but as a change in the ratio of energy used to services obtained. A concluding section discusses some implications, both for research and for energy conservation policy and programs, of a broadened perspective that embraces both physical and occupant effects on building energy performance.

232
Harris, J.P., Lawrence Berkeley Laboratory, Berkeley, CA

Monitored Energy Performance of New and Retrofitted Residential Buildings: Results from the BECA Data Base

LBL-19348; 18 pp.; CONF-850402; Consumer Behaviour and Energy Policy, Proceedings of the Second International Conference, Paris, France, April 10, 1985 (1985, June)

We summarize measured energy performance data, drawn from the "BECA" data base at LBL, on several hundred new and retrofitted residences. We explore the two-way relationship between occupant behavior and the physical characteristics and energy performance of residential buildings. A more detailed, empirical understanding of both physical and occupancy variables is needed to help explain the observed variance in energy performance among physically similar houses, as well as the variance between performance predictions and actual measurements. Physical and occupancy factors may be difficult to separate, in theory as well as in practice. The evaluation of "occupant effects" raises questions not only of sufficient data, but of inadequate definition of the outputs resulting from energy use: occupant comfort, well-being, and other "building services." Thus, energy efficiency is properly defined not as reduced consumption, but as a change in the ratio of energy used to services obtained. A concluding section discusses some implications, both for research and for energy conservation policy and programs, of a broadened perspective that embraces both physical and occupant effects on building energy performance.

233
Harrje, D.T., Princeton University, Princeton, NJ

Energy Conservation in Buildings, 1986-1987: Department of Energy Research Summary Report, 1986-1987

DOE/CE/23838-T3; PU/CEES-219; 27 pp. (1987, November)

Under the headings of Overview, Building Science and Retrofit Field Studies, this report summarizes the research accomplished with U.S. Department of Energy support under Grant DE-G01-86CE23838 covering the period July 1986 through April 1987. Details of the complete findings, as a result of this contract research, may be found by consulting the appropriate reports and technical papers listed under References. Many aspects of the research were actively assisted by outside collaboration as well as interaction with other DOE laboratories. Such activities are listed under Collaboration. The research generally falls into two categories: Building Science and Retrofit Field Studies.

234
Harrje, D.T., D.L. Bohac, and R.C. Fartman, Princeton University, Princeton, NJ

Measurement of Seasonal Air Flow Rates in Unoccupied Single-Family Residence

AIVC-PROC-8-87; Ventilation Technology-Research and Application, Proceedings of the Eighth AIVC Conference, Uberlingen, Federal Republic of Germany, September 21-24, 1987 (1987)

235
Harrje, D.T., D.L. Bohac, and D. Feuermah, Princeton University, Princeton, NJ

Extending Testing of a Multi-Family Building Using Constant Consideration and DFT Methods

AIVC-PROC-9-88-1; CONF-8809127; Effective Ventilation, Proceedings of the Ninth AIVC Conference, Ghent, Belgium, September 12-15, 1988. University of Warwick, Air Infiltration and Ventilation Centre, Coventry, United Kingdom, 1989; (18 pp.) (1988)

236
Harrje, D.T., and S.G. Duff, Princeton University, Princeton, NJ

Energy Conservation in Buildings Department of Energy Research Summary Report - 1980-1985

Princeton University Center for Energy and Environmental Studies Report No. 208 (1986, June)

237
Haugen, T., and H.E. Feustel, Lawrence Berkeley Laboratory, Berkeley, CA

Applications of a Simplified Model for Predicting Air Flows in Multizone Structures

LBL-23035; 37 pp.; Ventilation Technology-Research and Application, Proceedings of the Eighth AIVC Conference, Uberlingen, Federal Republic of Germany, September 21-24, 1987 (1987, July)

A simplified pocket calculator model has been developed which can simulate the air flow distribution in multizone structures. The model is based on lumped parameters and includes several assumptions to simplify the description of air flow due to wind and stack effect and their superimposition. This paper gives a brief overview of the model and describes several applications. Results for simulation runs using the simplified model are compared with results obtained from a mainframe based research tool. The examples show that the simplified method can be used to predict air mass flows within reasonable accuracy for different types of buildings. We are able to calculate air flows due to wind or stack effect within a few percent difference from results calculated with a detailed model. We might expect larger differences when superimposing flows caused by different effects.

238
Hawthorne, A.R., et al., Oak Ridge National Laboratory, Oak Ridge, TN

Indoor Air Quality in 300 Homes in Kingston/Harriman, Tennessee

ORNL-6401; 275 pp. (1988, July)

Supplemental indoor air quality measurements were conducted in the Kingston/Harriman area for radon, formaldehyde, polynuclear aromatic hydrocarbons, and airborne microorganisms. Eight groups of houses were chosen based on the presence or absence of the following sources: cigarette smoking, wood stoves, and kerosene heaters. Core measurements were made for a two-week period in each house during the winter season again during the summer season. In addition, both vapor phase and particulate phase polynuclear aromatic hydrocarbons were monitored. Viable airborne bacteria and fungi were also sampled in a large subset of houses. Preliminary results indicate that mean winter radon levels were 2.4 pCi/l and mean summer radon levels were 1.3 pCi/l (excluding basement measurements).

239
Heard, B., S.Y. Chu, C.A. Goldman, and J.F. Busch, Lawrence Berkeley Laboratory, Berkeley, CA

The CAL-BECA Project - Part 2: Energy Efficient California Residential Sub-Divisions

LBL-19294 (1985, February)

240
Heidell, J.A., R.P. Mazzucchi, and R.W. Reilly, Pacific Northwest Laboratory, Richland, WA

Commercial Building End-Use Energy Metering Inventory

PNL-5027; 120 pp. (1985, March)

Pacific Northwest Laboratory (PNL) has completed a comprehensive inventory of existing sources of measured end-use energy consumption data for commercial buildings that typify common design practices. The study comprises one task within the Commercial Buildings Metering Project, which is one element of the Commercial Buildings Energy Use and Design Program managed by PNL for the U.S. Department of Energy. The goal of the project is to provide an empirical, well documented, end-use energy consumption data base for researchers in the fields of building design, equipment manufacturing, public policy, energy-use simulation models, building control, and utility load forecasting.

241
Heidell, J.A., and Z.T. Taylor, Pacific Northwest Laboratory, Richland, WA

Comparison of Empirically Measured End-Use Metered Data with DOE 2.1 Simulation

PNL-SA-13096; 7 pp.; CONF-850817; Building Energy Simulation, Proceedings of a Conference, Seattle, WA, August 21, 1985 (1985, July)

This paper examines how well a DOE 2.1B simulation which has been calibrated for a 20,000 sq ft building reflects actual end-use energy consumption. Empirically measured data are compared with simulation results for end-use energy consumption, heating and cooling loads by thermal zone and month, monthly energy use, and monthly peak demand. The limitations of the DOE 2.1 code with respect to modeling the heat pump system are discussed and implications analyzed. An examination of schedules used to model the building highlights the importance of accurate information about building operation and its impacts on the simulation results.

242
Heidell, J.A., and Z.T. Taylor, Pacific Northwest Laboratory, Richland, WA

Field Measurements of Cooling Energy Consumption in a Multi-Zone Office Building

PNL-SA-13260; 13 pp.; CONF-8509126; Hot Humid Climate, Proceedings of a Conference, College Station, TX, September 24-26, 1985 (1985, June)

This paper discusses the cooling energy use in a small office building with the objective of developing an understanding of where energy is used and identifying relationships between cooling energy and other energy end uses. The goal is to translate this understanding into strategies for reducing cooling energy consumption in new buildings. The data presented in this paper are based upon empirical hourly end-use energy monitoring in a 20,500 sq ft office building located in Richland, WA. Hourly end-use energy and microclimate data have been collected for the past two years as a pilot metering project for a larger data collection effort in conjunction with the Commercial Building Energy Use and Design Program managed by Pacific Northwest

Laboratory for the U.S. Department of Energy. The office building metered, called Sigma IV, is a one story 20,500 sq ft building built in 1979. This building, part of a four building complex, typifies recent construction.

243
Hekmat, D., Lawrence Berkeley Laboratory, Berkeley, CA

Estimates of Impacts of Ventilation Air Heat Recovery on Energy Use for Water Heating

LBL-18562 (1985)

244
Hekmat, D., H.E. Feustel, and M.P. Modera, Lawrence Berkeley Laboratory, Berkeley, CA

Ventilation Strategies and Their Impacts on the Energy Consumption and Indoor Air Quality in Single-Family Residences

LBL-19376 (1986)

245
Hendrickson, P.L., Pacific Northwest Laboratory, Richland, WA

Liability Aspects of Home Energy-Rating Systems

PNL-4873; 68 pp. (1985, October)

The principal topic of this report is liability aspects of home energy rating systems. An introduction to the rating system concept including types of rating systems, implementation efforts to date, and possible groups to conduct ratings is also included. The home energy rating system concept involves the periodic rating of the energy efficiency of residential buildings. The rating can provide a relative indication of a home's energy efficiency and also a quantitative estimate of consumption, fuel cost, or both. This report is the fourth in a series of reports on the subject of home energy rating systems. These systems are designed to provide information on the relative energy efficiency of residential housing to housing consumers and professional people involved with residential housing. The principal focus of this report is on possible liability issues associated with implementation of a rating system.

246
Henly, J., A. Reid, and H. Ruderman

Determining the Effect of Efficiency Standards on the Use of Appliances

(1985)

247
Herrlin, M.K., and M.P. Modera, Royal Institute of Technology, Stockholm, Sweden; Lawrence Berkeley Laboratory, Berkeley, CA

Analysis of Errors for a Fan-Pressurization Technique for Measuring Inter-Zonal Air Leakage

LBL-24193; 20 pp.; AIVC-PROC-9-88-1; CONF-8809127; Effective Ventilation, Proceedings of the Ninth AIVC Conference, Ghent, Belgium, September 12-15, 1988. University of Warwick, Air Infiltration and Ventilation Centre, Coventry, United Kingdom, 1989; (pp. 215-232) (1988, September)

The lack of reliable measurements of the flow resistances between the zones of a multi-zone building is considered, and the uncertainties associated with a fan-pressurization technique for measuring the interzonal leakage are analyzed. The technique involves two blower doors, one in each of the two zones between which the leakage is being measured. A ventilation simulation program MOVECOMP is used to evaluate the technique.

248
Hirsch, J.J., Lawrence Berkeley Laboratory, Berkeley, CA

Plan for the Development of the Next-Generation Building Energy Analysis Computer Software

LBL-19830; CONF-850817; Building Energy Simulation, Proceedings of a Conference, Seattle, WA, August 21, 1985; (pp. 396-405) (1985)

Recent years have seen a number of building energy modelling systems reach the concluding phase of their development. Although these current systems offer sophisticated modelling capabilities, a number of deficiencies can be identified which will restrict any future adaptation to satisfy the needs of an increasingly demanding user community. Most of these systems were designed during the mid-1970's and were tailored in an inflexible manner for a now-outdated computing environment. Additionally, these systems were developed independently by groups around the world (mainly the U.S. and Europe) using different types of algorithms and solution techniques. Thus there is no way for these researchers to directly compare or exchange existing approaches; it is also difficult for them to collaborate on improving the existing systems. These problems are all solvable and it is against this background that a new idea has begun to emerge simultaneously from a number of research groups: to develop collaboratively a plan of work which will lead to a clear specification and subsequent development of the next-generation of building energy modelling systems.

249
Hirst, E.A., Oak Ridge National Laboratory, Oak Ridge, TN

Electric Utility Demand Side Programs and Integrated Resource Planning: Visits to Ten Utilities

ORNL/CON-195; 59 pp. (1986, March)

During Fall 1985, investor-owned electric utilities in California, Nevada, Washington, Wisconsin, New Jersey, New York, Connecticut, Massachusetts, and Maine were visited. The purpose of these visits was to discuss electric utility demand-side planning and programs, and to learn more about utility efforts to establish integrated resource planning processes. This report presents impressions of current electric utility activities in conservation and load management program planning, analysis, and evaluation; and in integrated demand/supply planning. The observations and suggested research topics presented were based on my authors impressions and observations. Other researchers, visits with different people in the same utilities, or visits with other utilities might yield different findings and conclusions.

250
Hirst, E.A., Oak Ridge National Laboratory, Oak Ridge, TN

Regulatory Responsibility for Utility Integrated Resource Planning

ORNL/CON-249; 39 pp. (1988, January)

Integrated resource planning is a very important issue for electric utilities and their state regulatory commissions. Although much has been written about the obligations of the utilities, very little has been published concerning the roles and responsibilities of the state public utility commissions (PUCs). This report is based on the assumption that integrated resource planning can yield substantial benefits to utilities, their customers, and to commissions. However, these benefits will not be fully realized unless commissions further develop their roles in improving the planning process and consequent plans. This report serves as an extended outline of issues that merit further consideration among commissions, the utilities they regulate and other interested parties. Because these issues are complicated and controversial, the report cannot provide definitive answers.

251
Hirst, E.A., Oak Ridge National Laboratory, Oak Ridge, TN

Effects of Energy-Efficiency Programs on Load-Growth Uncertainty for Electric Utilities

ORNL/CON-260; 42 pp. (1988, August)

Electric utilities face a variety of uncertainties that complicate their long-term plans to acquire future resources. These uncertainties concerns future load growth; the performance and lifetimes of existing generating plants; and the costs lead times, and performance of new demand and supply resources. Conservation programs can both provide cost-effective resources and reduce uncertainties. Programs that improve the energy-efficiency of new residential, commercial, and industrial buildings reduce uncertainty about the effects of economic growth on load growth.

252
Hirst, E.A., and R. Goeltz, Oak Ridge National Laboratory, Oak Ridge, TN

Energy Savings One and Two Years after Participation in Minnesota Home Energy Audit and Retrofit Loan Programs

ORNL/CON-168; 43 pp. (1985, January)

Northern States Power (NSP), the largest utility in Minnesota, operates several residential energy conservation programs. This report updates a 1983 detailed quantitative evaluation of two of these programs. The Minnesota Energy Conservation Service (MECS), Minnesota's version of the federal Residential Conservation Service, provides home energy audits and related services to households who live in structures with four or fewer dwelling units and pay gas or electricity bills to a utility participating in MECS. Between April 1981 and December 1982, NSP conducted almost 12 thousand audits. The focus of this update is on the energy-saving effects of the programs one and two years after participation. The original (1983) evaluation addressed several issues related to the effects and effectiveness of the MECS and PUCIP programs. The present update expanded the original data set by adding 13 months of natural gas billing data (from May 1983 through May 1984) and daily temperature data for the three relevant weather stations.

253
Hirst, E.A., and R. Goeltz, Oak Ridge National Laboratory, Oak Ridge, TN

Potential Vs. Practice: Installation of Retrofit Measures in the Hood River Conservation Project

ORNL/CON-189; 53 pp. (1985, September)

Although only half the eligible homes have completed the HRCP process, some conclusions can be drawn concerning penetration of retrofit measures. The following thoughts are based on the 1747 homes that had essentially completed participation in HRCP by the end of May 1985. HRCP and its extensive data collection processes yield valuable and unique information on the reasonable upper limits for a residential retrofit program in the Pacific Northwest. That is, the high level of retrofits included in the project and the substantial financial contribution from BPA minimize the importance of capital cost and existing levels of structure thermal performance, two major obstacles to retrofit in most programs. Removal of these barriers, coupled with the details provided on types and times of barriers, will greatly increase our knowledge of the practical limits of residential retrofit programs. Removal of these barriers is effective in getting recommended measures installed. Almost 90% of the measures recommended by the energy auditors were subsequently installed by the Project. These results demonstrate the feasibility of installing almost all recommended retrofit measures in a program that is well run and that pays for most of the retrofit cost.

254
Hirst, E.A., and R. Goeltz, Oak Ridge National Laboratory, Oak Ridge, TN

Electricity Use for Residential Space Heating: Comparison of the Princeton Scorekeeping Method with End-Use Load Data

ORNL/CON-203; 42 pp. (1986, April)

The Princeton Scorekeeping Method (PRISM) is the best known and most widely used method to adjust residential energy use data for differences in winter severity. Nevertheless, questions remain about the accuracy of its results, especially about its ability to accurately decompose total residential energy use into its space heating and nonspace heating components. This report compares PRISM results with submetered data obtained from homes in Hood River, Oregon. The data used for this analysis are being collected as part of the Hood River Conservation Project

(HRCP), a major residential retrofit demonstration project. HRCP data include whole-house and space-heating electricity uses, recorded at 15-minute intervals. Weather data are also recorded at 15-minute intervals, at the Hood River Experiment Station. Analyses and comparisons suggest that PRISM estimates of total electricity use (normalized annual consumption, NAC) are in almost perfect agreement with the annual totals of the whole-house load channel (total).

255
Hirst, E.A., R. Goeltz, and K. Keating, Oak Ridge National Laboratory, Oak Ridge, TN

Evaluation of a Financial Incentive Program: The BPA Residential Weatherization Program

CONF-8508111; Energy Conservation Program Evaluation: Practical Methods, Useful Results - Volume 1, Sessions 1-11, Proceedings of the Second National Conference, Chicago, IL, August 19, 1985; (pp. 72-82) (1985)

During 1982 and 1983, the Bonneville Power Administration (BPA) operated an interim Residential Weatherization Program (RWP) throughout the Pacific Northwest. Participating households received free home energy audits and financial assistance to help pay for installation of retrofit measures in their homes. Almost 104 thousand homes were retrofit during the two years that the program operated; BPA's program cost totaled almost $160 million. This paper summarizes the results of a comprehensive evaluation of the BPA program. The evaluation focused on the energy-saving effects of the program and on its economic costs and benefits.

256
Hirst, E.A., R. Goeltz, and D. Trumble, Oak Ridge National Laboratory, Oak Ridge, TN

Electricity Use and Savings in the Hood River Conservation Project

ORNL/CON-231; 69 pp. (1987, April)

The Hood River Conservation Project (HRCP) was intended to test the reasonable upper limits of a residential retrofit program. It was proposed by the Natural Resources Defense Council, funded by the Bonneville Power Administration and operated by Pacific Power & Light Company in the community of Hood River, Oregon. This three-year, $21 million research and demonstration project installed as many cost-justified retrofit measures in as many electrically heated homes in Hood River as possible. The retrofits were aimed at the building shell to reduce electricity use for space heating and at water heating retrofits; no heating or water heating equipment was replaced. This report discusses methods and results related to actual electricity use and savings produced by HRCP.

257
Hirst, E.A., and C. Knutsen, Oak Ridge National Laboratory, Oak Ridge, TN

Developing an Integrated Planning Process: An Electric Utility Case Study

ORNL/CON-247; 33 pp. (1988, January)

In early 1986, Puget Power established a Demand and Resource Evaluation (DARE) program, intended to improve the internal planning process and prepare a long-term integrated resource plan for the Company. This report describes DARE activities during its initial cycle, from establishment in February 1986 through submission of the first plan to the Washington Utilities and Transportation Commission in November 1987. Three specific examples of typical planning situations (problems and their resolution) are presented. The examples deal with the decision to adopt an integrated planning model as a supplement to the in-house corporate models, the amount of time required to carefully computer analysis, and the need to recognize that marginal cost-of-service analysis is not just a requirement imposed by the Commission but a valuable tool to understand the costs of serving individual end uses.

258
Hirst, E.A., D.L. White, E. Holub, and R. Goeltz, Oak Ridge National Laboratory, Oak Ridge, TN

Actual Electricity Savings for Homes Retrofit by the BPA Residential Weatherization Program

ORNL/CON-185; 52 pp. (1985, July)

The Bonneville Power Administration operated an interim Residential Weatherization Program during 1982 and 1983 throughout the Pacific Northwest region of Washington, Oregon, Idaho, and western Montana. The program offered free home energy audits and financial incentives (usually cash rebates) to help pay for installation of recommended retrofit measures in electrically-heated homes. Almost 104,000 homes were retrofit during the two years the program operated at a cost to BPA of almost $160 million. The purpose of this study is to analyze actual electricity savings for homes that participated in the BPA program. The electricity savings achieved by these homes and the relationships between actual and predicted savings, and in addition, those households with anomalously large and anomalously small (negative) electricity savings were examined.

259

Hodgson, A.T., J. Binenboym, and J.R. Girman, Lawrence Berkeley Laboratory, Berkeley, CA

A Multisorbent Sampler for Volatile Organic Compounds in Indoor Air

LBL-21378; 16 pp.; CONF-860606; Proceedings of the Air Pollution Control Association Annual Meeting and Exhibition, Minneapolis, MN, June 22, 1986 (1986, March)

A multisorbent sampler and a compatible gas chromatographic inletting system for the quantitative analysis of ppb concentrations of VOC in ambient and indoor air are described. The sampler contains a gradient of Tenax-TA, Ambersorb XE-340 and activated charcoal. Analytes are thermally desorbed from the sampler and are inletted in their entirety onto a capillary column by subsequent adsorption/therma l desorption steps. An on-column cryogenic focusing attachment enhances peak resolution and peak area response. A mass selective detector is used for qualitative and quantitative analyses. Sampler breakthrough volumes for representative low-boiling compounds are greater than or equal to 10 l. With a 10 l volume, limits of quantitation are less than 1 ppb. Overall precision is normally better than 5% RSD at analyte concentrations ranging between one and several tens of ppb. Accuracy for representative low-boiling compounds is typically plus or minus 5%. The applicability of the method is demonstrated by the quantitative analysis of VOC as a function of ventilation at a large office building.

260

Hodgson, A.T., K. Garbesi, R.G. Sextro, and J.M. Daisey, Lawrence Berkeley Laboratory, Berkeley, CA

Evaluation of Soil-Gas Transport of Organic Chemicals into Residential Buildings: Final Report

LBL-25465; 92 pp. (1988, June)

This investigation consisted of theoretical, laboratory, and field study phases with the overall objective of determining the importance of pressure-driven flow of soil gas in the transport of volatile organic compounds (VOC) from soil into a house. In the first phase, the mechanisms of advection, diffusion, and retardation of VOC in soil were evaluated. Using the theory of fluid mechanics and empirical for equilibrium partitioning of VOC among gas, aqueous, and solid phase of soil, a one-dimensional advection-diffusion equation or the transport of gas-phase VOC through soil was developed. An experimental apparatus and method were developed for the direct observation of pressure-driven transport of VOC through soil under controlled laboratory conditions. The retardation of sulfur hexafluoride (SF6) and hexafluorobenzene with respect to the flow of the bulk gas was measured in soil-column experiments using different soils and soil-moisture conditions. The results were in good agreement with theoretical predictions. Since SF6 was not lost by sorption to soil, it was selected for use as a tracer gas in the field study to study the advective flow of soil gas. The overall objective of the investigation was directly addressed by the field study. This study was conducted at a house which has a basement and which was located adjacent to a covered municipal landfill. The soil at the site was characterized, pressure coupling between the basement and surrounding soil was measured, the entry rate of soil gas as a function of basement depressurization was measured, and VOC in soil gas, indoor air, and outdoor air were quantified.

261

Hodgson, A.T., and J.R. Girman, Lawrence Berkeley Laboratory, Berkeley, CA

Exposure to Methylene Chloride from Controlled Use of a Paint Remover in Residences

LBL-23078; 40 pp.; CONF-870695; Proceedings of the 80th Annual Air Pollution Control Association Meeting, New York, NY, June 1, 1987; Paper No. 87-81.3 (1987, June)

A recent laboratory investigation characterized personal exposures to methylene chloride (CH2/Cl2) for simulated typical uses of paint removers and aerosol finishes containing CH2/Cl2 in a room-size environmental chamber at two ventilation rates. Because paint removers produced relatively large exposures to CH2/Cl2 in these experiments, the present investigation was undertaken to measure exposures to CH2/Cl2 for standardized use of a paint remover in a variety of residential environments. A total of 21 experiments were conducted outdoors and indoors in a garage, a basement workshop, and large and small rooms of a house. In the indoor work areas, ventilation patterns and rates were varied by opening windows and doors and by the use of a household fan. Finishes were removed from uniformly-prepared panels and from chairs. The personal exposure of the worker was determined from the continuous measurement of CH2/Cl2 concentration in a pumped breathing-zone sample. Personal exposures resulting from the outdoor use of paint remover were very low (6 to 36 ppM/hr). Exposures resulting from the use of paint remover indoors without mechanical exhaust ventilation were considerably higher (190 to 2090 ppM/hr). In each indoor location, an open window or exterior door (11 to 142 ppM/hr). A single-equation mass-balance model was used to produce estimates of theoretical exposures for experiments conducted indoors. The efficacy of the model for predicting exposures was evaluated by comparing theoretical and measured personal exposures. The model performed best for small-volume work areas with low ventilation rates. In general, the model had an accuracy of plus or minus 50 percent when applied to experiments conducted in enclosed work areas without an exhaust fan.

262

Hodgson, A.T., and J.R. Girman, Lawrence Berkeley Laboratory, Berkeley, CA

Application of a Multisorbent Sampling Technique for Investigations of Volatile Organic Compounds in Buildings

LBL-23087; 26 pp.; CONF-8704219; Design and Protocol for Monitoring Indoor Air Quality, Proceedings of the ASTM Symposium, Cincinnati, OH, April 26-29, 1987 (1987, August)

An analytical method for volatile organic compounds (VOC) which employs a multisorbent sampler containing, in series, Tenax-TA, Ambersorb XE-340, and activated charcoal is described. The method was evaluated in the laboratory and was used to measure concentrations of VOC at a school and an office building. The sampler quantitatively collects compounds spanning a broad range of boiling points, including highly volatile solvents. The overall precision of the method is better than ten percent and often better than five percent. The composition and concentrations of VOC in the two, approximately five-month old, non-residential buildings were similar and also similar to the composition and concentrations in typical residential indoor air. Concentrations of VOC were measured at two ventilation rates in both non-residential buildings, and the data were applied to a single-equation mass-balance model. Apparent specific source strengths for VOC approximately doubled with a six-fold increase in ventilation rate.

263
Howett, G.L., National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Linear Opponent-Colors Model Optimized for Brightness Prediction

NBSIR-85-3202; 125 pp. (1986, February)

Formal multivariate optimization techniques were applied in an attempt to determine how well a linear, opponent-colors model of color vision could account for specific brightness-matching data. The data fitted were from a single experiment by Sanders and Wyszecki that matched an adjustable white light in brightness to each of a set of lights of 96 different colors and constant luminance. A generalized, linear, opponent-colors model was formulated, which included the models of Guth (and coworkers), Ingling (and coworkers), and Thornton as special cases. The model contained 10 parameters, including nine determining the spectral responses of the three opponent-level channels, and one determining the rule for combining the outputs of the three channels to obtain an estimate of equivalent luminance (the luminance of an equally bright white light). Despite difficulties with the optimization procedure, a model was found that correlates better than 0.98 with the fitted data. The predictions of this model for various other color-vision functions were explored and compared with corresponding predictions of the Guth and Lodge model and the Thornton model. The new model's predictions of these functions are less than perfect, but surprisingly good considering that the model was optimized entirely on brightness data (the only restriction being that the luminance channel should not have any negative values). The model was shown to predict the sort of complex mixture of sub- and superadditivity that is present in actual data. Some new algebraic results concerning the "B/Y" or "B/L" (equivalent luminance over luminance) ovals on the chromaticity diagram were derived.

264
Huang, Y.J., R.L. Ritschard, and J. Bull, Lawrence Berkeley Laboratory, Berkeley, CA

Simplified Calculations of Energy Use in Residences Using a Large DOE-2 Data Base

LBL-20107 (1985)

265
Huang, Y.J., R.L. Ritschard, J. Bull, and L. Chang, Lawrence Berkeley Laboratory, Berkeley, CA

Climatic Indicators for Estimating Residential Heating and Cooling Loads

LBL-21101; 59 pp.; CONF-870101; Proceedings of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers Meeting, New York, NY, January 18-21, 1987 (1986, November)

An extensive data base of residential energy use generated with DOE-2.1A simulation code provides an opportunity for correlating building loads predicted by an hourly simulation model to commonly used climatic parameters such as heating and cooling degree-days, and to newer parameters such as insulation-days and latent enthalpy-days. The identification of reliable climatic parameters for estimating cooling loads and the incremental loads for individual building components, such as changing ceiling and wall R-values infiltration rates or window areas is emphasized.

266
Huang, Y.J., R.L. Ritschard, S. Byrne, I. Turiel, and G. Wilson, Lawrence Berkeley Laboratory, Berkeley, CA

Affordable Housing Through Energy Conservation: A Guide to Designing and Constructing Energy Efficient Homes

LBL-16343 (1985)

267
Hughes, P.J., R.J. Hackner, and A.S. Fleming, Associates, Inc., Syracuse, NY

Field Performance Validation of an Advanced Design Earth-Coupled Heat Pump System

ORNL/Sub-85/22035/1; 105 pp. (1988)

Oak Ridge National Laboratory, Niagara Mohawk Power Corporation, and W. S. Fleming and Associates, Inc. conducted a field-test program to evaluate prototype earth-coupled heat pump systems in two upstate New York homes. Each site utilized a prototype liquid source heat pump designed specifically for the earth-coupled source heat. Results show that the prototype heat pumps provided efficient operations at source temperatures as low as 27 deg F, enabling shorter earth loops to be installed.

268
Hunn, B.D., M.L. Baughman, S.C. Silver, A.H. Rosenfeld, and H.A. Akbari, Lawrence Berkeley Laboratory, Berkeley, CA; University of Texas, Austin, TX

Electrical Energy Conservation and Peak Demand Reduction Potential for Buildings in Texas: Preliminary Results

LBL-20508; 11 pp.; CONF-8509126; Hot Humid Climate, Proceedings of a Conference, College Station, TX, September 24-26, 1985 (1985, September)

This paper presents preliminary results of a study of electrical energy conservation and peak demand reduction potential for the building sector in Texas. Starting from 1980 building stocks and energy use characteristics, technical conservation potentials were calculated relative to frozen energy efficiency stock growth over the 1980-2000 period. The application of conservation supply methodology to Texas utilities is outlined, and then the energy use and peak demand savings, and their associated costs, are calculated using a prototypical building technique. Representative results are presented, for residential and commercial building types, as conservation supply curves for several end use categories.

269
Hunn, B.D., M.L. Baughman, S.C. Silver, A.H. Rosenfeld, and H.A. Akbari, Oak Ridge National Laboratory, Oak Ridge, TN; Center for Energy Studies, Austin, TX; Lawrence Berkeley Laboratory, Berkeley, CA

Technical Potential for Electrical Energy Conservation and Peak Demand Reduction in Texas Buildings

LBL-21831; UT-CES-8015270 (1986, February)

This report presents the results of a preliminary study of the potential for electricity conservation and peak demand reduction in the Texas buildings sector. The results show that with implementation over 20 years of cost-effective measures identified in this study (those with costs of conserved energy less than 8 phi/kW/hr), potential electricity savings of approximately 50 billion kW/hr/yr are indicated. These savings are nearly one-third of the statewide building electricity use projected at frozen efficiency (that is, with no additional energy conservation efforts beyond 1980 characteristics) for the year 2000.

270
Hust, J.G., J.E. Callanan, and S.A. Sullivan, Oak Ridge National Laboratory, Oak Ridge, TN

Specific Heat of Insulations

ORNL/IA-21428/1

271
Hutchinson, R.A., Pacific Northwest Laboratory, Richland, WA

Oil-Fired Equipment Research: Program Plan

PNL-5896; 58 pp. (1986, September)

The purpose of this document is to define the basis for a U.S. Department of Energy (DOE) program for oil-fueled equipment research. The needs for an benefits of the technical research are explained, and a research plan is presented. This program was developed by Pacific Northwest Laboratory (PNL) with assistance from Steven Winters Associates and input from Brookhaven National Laboratory, Oak Ridge National Laboratory, and many representatives of the heating-oil and oil-fueled equipment industries. The private sector input was extensive, obtained through a series of workshops and formal and informal surveys. The planning effort was directed by the Building Equipment Division of the DOE Office of Buildings and Community Systems. The objective of the oil-fueled equipment research program is to develop the technological basis for new equipment and operating strategies based on improved understanding of oil-burning fundamentals. The program will provide the oil-fueled equipment industry with the basis for developing a new, high-tech generation of equipment, and the oil distributors and equipment installers and consumers with improved knowledge of how best to install and operate such equipment.

272
Ingersoll, J., and J. Juang, Lawrence Berkeley Laboratory, Berkeley, CA

Heating Energy Use Management in Residential Buildings By Temperature Control

Energy and Buildings 8(1):27 (1985)

Results of an analytical investigation to determine the potential heating energy savings that can be achieved in a residential building by controlling the house temperature or through night setback or net setback plus day zone setback. The objective of this study is to quantify the energy savings resulting from different temperature control strategies so that comparisons of their significance can be made.

273
Janssen, J.E., and R.W. Rasmussen, Oak Ridge National Laboratory, Oak Ridge, TN; Honeywell, Inc., Golden Valley, MN

Final Report of Research and Development of a Diagnostic Procedure to Measure Changes in Thermal Integrity of Building Envelopes: Phase 2 - BTR Meter Development

ORNL/Sub-83/47959/2; 71 pp. (1988, December)

Previous work ("Application of Building Thermal Resistance Techniques" by J.E. Janssen, "Comparison of BTR Measurements" by J.E. Janssen and A.N.J. Pearman) has shown that the overall Building Thermal Resistance (BTR) of a typical home can be measured by observing the rate of temperature fall when the furnace is off and the rate of temperature rise when the furnace is turned on for 90 minutes. An instrument, based on an Epson Notebook computer, was built, and the computer was programmed to record the measured temperatures and compute the BTR value. An interactive program guides the user in the operation of the instrument. BTR measurements on three test houses agreed with ASHRAE heat loss calculations within minus 6% and plus 9%. The BTR meter offers a simple and convenient way to assess the condition of the thermal insulation in an existing residential structure. No other method is available for such an overall measurement with relatively unskilled labor. The meter should be useful to building inspectors, builders, real estate people and sales people. For example, it has been shown that the method can discriminate between the presence and absence of storm windows. The instrument can also be used to make gross measurements of infiltration. While the BTR meter works best with warm air heating systems, its use is limited only by the ability to measure a representative indoor air temperature and the knowledge of the true heat input to the building when the heating system is operating at steady state. Further wide-scale testing of the meter is needed to establish its credibility.

274
Janssen, J.E., and R.W. Rasmussen, Honeywell, Inc., Minneapolis, MN

Research and Development of a Diagnostic Procedure to Measure Changes in Thermal Integrity of Building Envelopes

ORNL/Sub-84/47959/1; 75 pp. (1985, June)

A transient heat flow method is presented for measuring the overall envelope conductivity (or thermal resistance) of a residential-type building. The rate of indoor temperature decay when the heating system is off and the rate of temperature rise when the heating system is on continuously for about 1 hour provide the data needed to separate heat storage effects from the heat conductivity through the structure. Detailed measurements on one house gave results within about 2% of the calculated values. It is shown that infiltration losses can be measured by making thermal measurements under several infiltration conditions. It also is shown that the effect of adding a third pane of glass to a thermopane window can be detected and measured.

275
Jewett, D.L., et al., Lawrence Berkeley Laboratory, Berkeley, CA

Lack of Effects of Human Muscle Strength of the Light Spectrum and Low Frequency Electromagnetic Radiation in Electric Lighting

LBL-20615 (1985, November)

The transverse profile of the monochromatic radiance of an optically thick resonance line from a cylindrical discharge is inverted exactly to give the radial distribution of radiating atoms. In contrast to the Abel transform, this result is valid for all optical depths.

276
Johnson, D.R., Pacific Northwest Laboratory, Richland, WA

Building Energy Conservation Decision Process Model

PNL-SA-13404 (1985, September)

277
Johnson, D.R., D. Arasteh, D. Connell, and S. Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

Effect of Daylighting Strategies on Building Cooling Loads and Overall Energy Performance

LBL-20347; 21 pp.; CONF-851202; Thermal Performance of the Exterior Envelopes of Buildings - III, Proceedings of the DOE-ORNL-ASHRAE-BTECC Conference, Clearwater Beach, FL, December 2, 1985, 1421 pp. (1986, January)

It has been demonstrated that daylighting, by reducing electric lighting requirements, is one of the most effective energy-conservation strategies in office building envelope design. Additionally, because the luminous efficacy of daylight outdoors is higher than that of most electric lighting systems, it is frequently assumed that buildings designed for daylighting will have smaller cooling loads than similar buildings not designed for daylighting. This assumption is valid only within certain specific design limits. Outside these limits, daylighting may increase cooling loads, requiring larger chillers and associated cooling equipment, and may seriously compromise or even negate the economic benefits of reduced electric lighting use. In this paper we discuss these limits, the luminous efficacy of delivered daylight is sidelighted and toplighted spaces, methods of enhancing efficacy, and the resultant overall energy and economic impacts of daylighting design.

278
Johnson, D.R., J.M. Fang, and D.L. Ivey, Pacific Northwest Laboratory, Richland, WA

Energy Conservation Strategies and the Use of Market Research in Time of System Surplus

PNL-SA-13767; 9 pp.; CONF-8604109; Productivity Through Energy Innovation; Proceedings of the Pacific Gas and Electric (PG and E) Energy Exposition, Oakland, CA, April 29, 1986. Pergamon Books, Inc., Elmsford, NY (1986, February)

Energy Conservation programs have become recognized as effective tools for utilities interested in deferring the need for new generating units. However, many utilities currently find themselves in circumstances in which generating capacity exceeds demand. This paper explores appropriate conservation strategies under these circumstances. The general approach is to build the capability to quickly acquire conservation resources in the future when they are needed, using market segmentation and market research. A strategy for some market segments involves maintaining and reinforcing the likelihood of future investment in energy conservation. A separate strategy involves cultivating other market segments to increase the likelihood of future investment.

279
Johnson, K., and S. Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

Light Guide Design Principles

LBL-20546; 24 pp.; CONF-861109; Architecture and Natural Light, Proceedings of the Second International Daylighting Conference, Long Beach, CA, November 5-7, 1986 (1986, November)

A general theory of optical transport systems has been developed that can be used to determine preliminary design specifications for light guide systems. Several generic light guide types are analyzed, including hollow reflective light guides, prism light guides, solid dielectric and fluid-filled light guides, lens guides, and open light wells. Minimum theoretical aperture requirements are determined for each type as a function of the specified optical transport efficiency and design parameters (light guide length, transmitted luminous flux, etc). Generally, a system's aperture requirement would be inversely related to its cost. Solid dielectric (e.g., optical fiber) light guides would be very compact and practical for retrofit applications, but their high cost option, but would require the greatest aperture area. Hollow reflective light guides, prism light guides, or lens guides may offer the best compromise between cost and space requirements. But in order to achieve optical concentrations and efficiencies near the theoretical limit, the collector system would need to maintain optical and tracking tolerances exceeding the capabilities of existing systems so further advances in core daylighting will require improvements in collector technology.

280
Johnson, R., D. Arasteh, and S. Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

Energy Reduction Implications with Fenestration

LBL-19304; 8 pp.; CONF-850804; Heating, Ventilating and Air Conditioning, Proceedings of the World Congress International Exhibition, Copenhagen, Denmark, August 25, 1985 (1985, March)

In this paper the authors discuss results from a number of parametric analyses of the energy and cost influences of fenestration in a prototypical office building. The energy important parameters of fenestration, daylighting, and electric lighting were systematically varied in several climates using the DOE-2.1 energy simulation program to determine net annual results. Results are presented for two climate extremes; one heating-load dominated and the other cooling-load dominated. The increase or decrease of net annual energy consumption and peak electrical demand due to fenestration is demonstrated. Daylighting is shown to be the single most important strategy to reduce energy use, but can be an energy and cost liability. Conditions under which these liabilities occur are discussed, and optimal design solutions for minimizing energy costs are suggested.

281
Johnson, R., D. Connell, S. Selkowitz, and D. Arasteh, Lawrence Berkeley Laboratory, Berkeley, CA

Advanced Optical Materials for Daylighting in Office Buildings

LBL-20080; 13 pp.; CONF-851030; Solar '85, Proceedings of the 1985 Annual American Solar Energy Society Meeting, Raleigh, NC, October 15, 1985 (1985, December)

The use of daylighting to supplant electric light in office buildings offers substantial energy savings and peak electrical demand reductions. The benefits from electric lighting reductions can, however, be easily offset by increased cooling loads if solar gains are not controlled. The use of advanced glazing materials having optical switching properties can facilitate solar control and, with proper design, maximize energy and cost benefits. The potential net annual performance of these materials, based on simulation studies using DOE-2.1C, are discussed in this paper. Actively and passively controlled response functions are analyzed for the cooling-load-dominated climate of Lake Charles. The effects of advanced materials on net annual energy consumption, peak electrical demand, and chiller size are compared with those of conventional materials. The results demonstrate the importance of operable solar control to achieve energy-effective daylighting design. Advanced optical materials that provide the necessary level of control are shown to minimize peak electrical demand and electricity consumption.

282
Johnson, R., et al., Lawrence Berkeley Laboratory, Berkeley, CA

Glazing Energy Performance and Design Optimization with Daylighting

Energy and Buildings 6(3):305 (1984)

This study systematically explores the influences of glazing systems on component loads and annual energy use in prototypical office buildings. Conditions under which daylighting reduces net annual energy use as well as those under which energy use may increase are examined. A principle concern of the study is identifying fenestration, designs that will maximize energy conservation benefits with the use of daylight, and to compare the energy performances of design options.

283
Johnson, W.S., et al., Oak Ridge National Laboratory, Oak Ridge, TN

1984-1985 Annual Performance Testing and Analysis of Two Horizontal Coil Ground-Coupled Heat Pump Systems

ORNL/Sub-81/7685/4&92 (1987, April)

284
Johnson, W.S., B.A. McGraw, R.N. Baugh, and W.A. Griffith, University of Tennessee, Knoxville, TN; Oak Ridge National Laboratory, Oak Ridge, TN

Ground-Coupled Heat Pump Research at the University of Tennessee

CONF-841231; Research and Development on Heat Pumps for Space Conditioning Applications, Proceedings of the DOE/ORNL Heat Pump Conference, Washington, DC, December 10, 1984; (pp. 123-129) (1985, August)

The ground has been considered for the heat sink and heat source for heat pumps since their initial application in residential heating and cooling because the ground is normally at a more favorable temperature than the ambient air. Ground coupled heat pump research at Brookhaven National Laboratory including the testing of four buried tanks, six earth coils and six sealed vertical wells is summarized. A heating seasonal performance factor of 2.3 for a horizontal ground coil in Upton, New York is reported. This study was undertaken to evaluate the seasonal performance of a horizontal-coil ground-coupled heat pump system in both the heating and cooling mode to determine its potential for use in the Knoxville, TN area. In addition, the effects of the most significant parameters on performance were to be determined along with the required data to develop an optimized system.

285
Johnson, W.S., B.A. McGraw, R.N. Baugh, and W.A. Griffith, University of Tennessee, Knoxville, TN

TECH House I Horizontal Coil Ground Coupled Heat Pump: 1983-1984 Annual Performance

ORNL/Sub-81/7685/3&92; 66 pp. (1985, August)

Performance of the horizontal coil ground coupled heat pump (GCHP) system in TECH House I at the Tennessee Energy Conservation in Housing Facility is reported for the 1983-1984 heating season and the 1984 cooling season. The annualized seasonal performance factor (ASPF) for this period was measured to be 2.10.

286

Johnson, W.S., B.A. McGraw, R.N. Baugh, S.D. Wix, and F. Conlin, University of Tennessee, Knoxville, TN

TECH House I Horizontal Coil Ground Coupled Heat Pump: 1983 Cooling Season Performance

ORNL/Sub-81/7685/2&92; 51 pp. (1984, May)

Performance of the ground-coupled heat pump system in TECH House I at the Tennessee Energy Conservation in Housing Facility is reported for the summer of 1983. The overall seasonal performance factor (SPF) was 1.11 with the system located within the conditioned space. If the system had been outside the conditioned space, an SPF of 1.31 would have been realized. This low performance level, below that of a conventional air-to-air heat pump, is primarily due to poor performance of the ground heat exchanger. Degraded soil heat transfer characteristics due to drying and the occurrence of voids around the pipe in the trench backfill were primary reasons for poor performance. In addition, it appears that the underground coil length needs to be increased in order to match the peak cooling loads of the house. The sensible load on the house was met by the system only for ambient temperature below 98 F. The latent load was often not met because the inside coil temperature was not sufficiently below the dew point temperature of the inside air.

287

Johnson, W.S., B.A. McGraw, A.F.G. Bedinger, F. Conlin, and S.D. Wix, University of Tennessee, Knoxville, TN

TECH House I Horizontal Coil Ground Coupled Heat Pump: 1982-1983 Heating Season Performance

ORNL/Sub-81/7684/1&92; 71 pp. (1984, February)

A ground-coupled heat pump (GCHP) system having a 200 m (675 ft) horizontal serpentine ground coil was installed at the Tennessee Energy Conservation in Housing (TECH) facility. Experimental results for the 1982-1983 heating season showed a heating seasonal performance factor (SPF) of 2.60. Had the system been located outside the conditioned space the SPF would have been 2.04. No auxiliary electric heat was required. Soil temperature measurements indicate that the ground near the pipe never went below 0 C. A discussion of soil moisture measurement techniques and devices is included. Moisture sensors have been installed near the coil and will be used to determine drying trends during the 1983 cooling season.

288

Jordan, A.A., Institute of Applied Physics, Delft, Netherlands

Computer Program for Calculating the Daylight Level in a Room

Energy and Buildings 6(3):207 (1984)

A computer program has been developed that calculates the total quantity of daylight provided to an arbitrary place in a room by direct incident daylight, by reflected daylight from opposite buildings and ground and by interreflected daylight from walls, ceilings and floors. The program calculates daylight levels at all places in the room. The calculation is based on view factors and total exchanges factors between rectangular surfaces.

289

Jou, W.H., G.S. Knoke, and C.M. Ho, Oak Ridge National Laboratory, Oak Ridge, TN

Entrainment Enhancement of a Supersonic Jet for Advanced Ejectors

CONF-8804100; Research and Development on the Heat Pump for Space Conditioning Applications, Proceedings of the Second DOE/ORNL Heat Pump Conference, Washington, DC, April 17-20, 1988, 225 pp.; (7 pp.) (1988)

Improved ejector performance is required for heat-actuated heat pump applications. Laboratory experiments were conducted to investigate the use of a new rectangular supersonic nozzle configuration for mixing enhancement.

Noncircular nozzles were previously found to increase substantially the jet entrainment in subsonic flow. Both flow visualization using schlieren photographs and pitot measurements in the far field indicate that the improvement in mixing for a supersonic jet is as good as that for a subsonic jet if not better. Mixing enhancement using a rectangular jet provides a technology basis for the development of the desired ejectors for heat pump applications.

290
Kaetzel, L., J. Grimes, and P. Brown, National Bureau of Standards, Washington, DC

Modular Data Acquisition and Display Software for a Laboratory Environment Final Report

NBS/TN-1188; PB-84-217892; 63 pp. (1984)

This report describes the process involved in acquiring and analyzing experimental laboratory data using a medium sized computer in a multi-programming environment with a modular software system. The software system consists of computer programs which allow the researcher to collect, store and analyze data graphically.

291
Kahn, E., Lawrence Berkeley Laboratory, Berkeley, CA

Proxy Plant Valuation Methods for Demand-Side Utility Program

LBL-21525 (1986, May)

292
Kahn, E., et al., Lawrence Berkeley Laboratory, Berkeley, CA

Value of Demand Side Utility Programs

LBL-21524 (1986)

293
Kahn, E., C. Pignone, J.H. Eto, J.E. McMahon, and M.D. Levine, Lawrence Berkeley Laboratory, Berkeley, CA

The Effect of Conservation Programs on Electric Utility Earnings: Results of Two Case Studies

LBL-21098; 24 pp. (1984, August)

This paper develops methods to measure the impact of conservation programs on electric utility earnings. The methods are applied to two case studies. Detroit Edison represents a case where impacts are unfavorable. This utility has "excess capacity" which is only made worse by conservation. Pacific Gas and Electric represents a case where conservation helps defer the need for new capacity. Even in this case, programs targeted at summer peak demand are more beneficial than those which save baseload energy. Conditions determining the earnings impact of conservation are complex, involving regulatory factors that are specific to individual utilities.

294
Kao, J.Y., National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Control Strategies and Building Energy Consumption

CONF-850606; Proceedings of the Semiannual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Honolulu, HI, June 23-26, 1985; ASHRAE Transactions 91(2B):810-817 (1985)

This is a summary report of building energy studies on basic control strategies applied to air-handling systems of four different buildings in six climatic regions. The building energy program BLAST is used to simulate commonly used air-handling systems for two office buildings, a school, and a retail store. The results of the cooling and the heating energy consumption of these buildings are presented and compared. The energy effects of various economy cycles and temperature resetting strategies applied to reheat, variable air volume, dual-duct, and other systems are discussed.

295
Karayel, M., M. Navvab, E. Ne'eman, and S.

Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

Zenith Luminance and Sky Luminance Distributions for Daylighting Calculations

Energy and Buildings 6(3):283 (1984)

Zenith luminance is integral to many daylight availability calculations. Authors present results of a study of zenith luminance in which systematic automatic and manual measurements were made for three years in San Francisco, California. The collected data are analyzed statistically to determine parameters and functional relationships.

296
Karvelas, D.E., J. Kaminsky, and E. Peters, Argonne National Laboratory, Argonne, IL

Low-Temperature District Heating/Cooling Energy Extraction from Flooded Abandoned Mines Using Downhole Heat Exchangers

Proceedings of an International District Heating and Cooling Association Exposition, Minneapolis, MN (1985, June)

297
Karvelas, D.E., J. Kaminsky, E. Peters, and T.N. Veziroglu, Argonne National Laboratory, Argonne, IL

Energy Extraction via Downhole Heat Exchangers in Flooded Abandoned Mines: Applications for District Heating and Cooling

CONF-851201; Alternative Energy Sources VII - Volume 3: Indirect Solar/Nuclear, Proceedings of the Seventh International Conference, Miami Beach, FL, December 9, 1985. Hemisphere Publishing Company, New York, NY; (pp. 241-250) (1985)

District heating and cooling (DHC) is a method by which thermal energy from a central source is distributed to residential, commercial, and industrial consumers for use in space heating, cooling, water heating, and process heating. The central source may be one of any number of options best suited for a DHC system, such as boiler units, a refuse incinerator, a geothermal source, solar energy, or one that utilizes heat developed as a by-product of electrical generation. Low-temperature energy sources represent a large potential energy source for DHC systems; such sources include lakes, groundwater aquifers, flooded mines, sewage ponds, and power plant cooling systems and stack heat. Many such sources are located close to high-energy-use areas and could be easily utilized as low-cost energy sources for future DHC projects. Before these low-temperature energy sources can be fully utilized in DHC systems, however, cost-effective heat extraction technologies must be developed and the economic viability of their use demonstrated.

298
Kasza, K.E., U.S. Choi, and J. Kaminsky, Argonne National Laboratory, Argonne, IL

Optimal Energy Transmission Fluids for District Heating and Cooling Applications

CONF-870620; Proceedings of the Annual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Nashville, TN, June 28, 1987; (16 pp.) (1987, May)

The U.S. Department of Energy is sponsoring the development of improving energy transmission fluids for district heating and cooling (DHC) applications through a long range program to: (1) identify and develop high performance thermal-hydraulic energy transmission fluids; (2) demonstrate that these fluids reduce frictional losses and improve heat transfer, resulting in storage tanks; and (3) generate friction and heat transfer correlations and systems performance information needed for design of improved DHC Systems.

299
Kedl, R.J., and T.L. Bircher, Oak Ridge National Laboratory, Oak Ridge, TN

Energy Conservation Case Studies for Model Commercial Buildings Covered by the CACS

Program

ORNL/CON-133; 132 pp. (1985, March)

Case studies of four small commercial buildings are presented that show potential conservation of gas energy. This document is intended to provide for small commercial buildings, a database on energy use patterns, and energy conservation potential resulting from the retrofit of measures and procedures defined in the CACS Program. This data base will be useful to states and utilities as they develop their audit procedures.

300
Kedl, R.J., and T.K. Stovall, Oak Ridge National Laboratory, Oak Ridge, TN

Cost-Effectiveness of Single and Multiple CACS Conservation Actions in Small Commercial Buildings

ORNL/CON-176; 63 pp. (1985, August)

The cost-effectiveness of single and multiple retrofit energy conservation actions in small commercial buildings is presented. This information will be useful to states and utilities as they develop audit procedures under the Commercial and Apartment Conservation Service (CACS) Program. Four small commercial buildings, prototypical of those covered by CACS, in six different cities are considered. The energy savings were computed using DOE-2.1, an hourly simulation computer code. The retrofit was assumed to be installed by a professional, and two electric rate schedules were used. Using terminology for conservation actions as defined by the CACS Rule, reduced light levels; the addition of local switches; and automatic controls for heating, ventilation, and air conditioning systems were always found to be cost-effective (simple payback period less than 5 years) everywhere. Air conditioner replacement was found to be generally cost-effective in the hot climates, and furnace replacement was only modestly cost-effective in the coldest climates. Building envelope retrofits, such as ceiling insulation, wall insulation, and caulking/weather stripping, were generally cost-effective, or nearly so, in the colder climates but only slightly cost-effective in the warmest climates; storm/thermal windows and storm doors were not cost-effective anywhere.

301
Kessel, J., Lawrence Berkeley Laboratory, Berkeley, CA

Transmittance Measurements in the Integrating Sphere

LBL-18234; Applied Optics 25:2752 (1986, August)

302
Ketoff, A., Lawrence Berkeley Laboratory, Berkeley, CA

Government Spending for Energy Conservation R and D: A Comparison of Selected OECD Countries

LBL-21185 (1986, March)

303
Kiel, D., D.J. Wilson, and M.H. Sherman, University of Alberta, Alberta, Edmonton, Canada; Lawrence Berkeley Laboratory, Berkeley, CA

Air Leakage Flow Correlations for Varying House Construction Types

LBL-18732; 21 pp.; CONF-850606; Proceedings of the Semiannual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Honolulu, HI, June 23-26, 1985 (1986, March)

Fan pressurization techniques are being employed by an increasingly large number of contractors and auditors to determine the leakage characteristics of structures. In this study, a large data base of flow exponents and flow coefficients are compiled to determine the degree of correlation that exists between flow parameters. The resulting empirical relationships are then used to determine the feasibility of predicting these flow parameters directly from a single pressure difference test. On the basis of these correlations, a new pressure independent tightness parameter is proposed.

304
Kier, P.H., Argonne National Laboratory, Argonne, IL

A Study of Direct Installation and Demonstration Workshop Programs to Reduce Residential Energy Consumption

ANL-CNSV-TM-161 (1985)

Two types of programs for conserving energy used for space heating, space cooling, and domestic water heating in residential buildings with one to four dwelling units is discussed and assessed. One type of program directly installs or ensures the installation of weatherization measures; the other features workshops that demonstrate the installation and use of weatherization measures, encourage energy-conserving behavior, and provide kits of low-cost measures in some instances. Information was gathered on nearly 60 programs. However, for only 10 of them were both cost and energy savings data available to allow a comparison of effectiveness. With the ratio of total cost to average annual energy savings taken as the measure of program effectiveness, it was found that programs installing low-cost measures, usually infiltration measures, had simple payback periods of two years or less and significantly smaller cost/energy savings ratios than programs installing major weatherization measures, such as insulation and storm windows.

305
Kier, P.H., and M.L. Meshenberg, Argonne National Laboratory, Argonne, IL

State Laws and Regulations Affecting Developments and Renovation of District Heating and Cooling Systems

ANL-CNSV-63 (1987, September)

This study of how state legislation affects development and renovation of district heating and cooling (DHC) systems has two focal points: for inventor-owned systems, it examines public utility regulation, while for publicly owned systems, it looks at local government law. Statutes and case law were studied, and officials of several DHC systems were contacted, to identify problems imposed by the legal and regulatory framework and to learn how these problems can be resolved through changes in either the DHC systems or the statutes. The study revealed 50% pieces of legislation that encourage or facilitate DHC systems (and that indicate problems and potential solutions). The content of this legislation was then used to construct drafts of two model statutes. The first, related to public utility regulation, adopts the limited-regulation approach of three western states in eliminating the most burdensome aspects of such regulation, including traditional rate regulation, while protecting customers. The second model statute, related to local government law, allows joint formation of DHC authorities by local government.

306
Kier, P.H., and M.L. Meshenberg, Argonne National Laboratory, Argonne, IL

Recent State Legislation That Encourages Development of DHC (District Heating and Cooling) Systems

CONF-870621; Proceedings of the 78th Annual International District Heating and Cooling Association Conference, Baltimore, MD, June 21, 1987; (7 pp.) (1987)

While studying how state legislation affects the development of district heating and cooling (DHC) systems, research uncovered more than forty recently-enacted statutes in nearly thirty states that in some way encourage the development or operation of DHC systems. The content of these pieces of legislation indicates the variety of potential legal/regulatory problems that confront DHC systems and the legislative approaches to resolving those problems. These statutes do one or more of the following: exempt certain thermal energy producers or DHC systems from public utility regulation; provide for limited public utility regulation of some DHC systems; authorize state agencies to make loans to DHC systems or thermal energy producers; enable public entities to own DHC systems or thermal energy production facilities; or enable public entities to purchase from DHC systems.

307

Kim, J.J., K. Papamichael, and S. Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

Development of Regression Equations for a Daylighting Coefficient-of-Utilization Model

LBL-20539; 15 pp.; CONF-861109; Architecture and Natural Light, Proceedings of the Second International Daylighting Conference, Long Beach, CA, November 5-7, 1986 (1986, November)

When hourly energy simulation models are used to predict the performance of multi-zone buildings, they may be required to perform more than 2000 daylight analyses in a single simulation. The traditional approach is to use a very fast computational model, which of necessity must be a very simple model. Coefficient of utilization models have been widely used as simple design tools but have been severely limited in their applicability to complex and realistic fenestration systems and building designs. This paper present a new coefficient of utilization (CU) model for daylighting that combines the ease of use of CU models with the ability to predict illuminance under a wide range of conditions. The model consists of seven regression equations normalized to exterior vertical surface illuminance. These equations describe daylight illuminance as a function of position in a room and are sensitive to all of the significant design variables. The equations are derived from parametric analysis using a mainframe daylighting computer model (SUPERLITE). We describe how these equations were developed and their physical and theoretical background. Comparisons between direct calculation and CU results for sample rooms are demonstrated.

308

Klemens, P.G., Oak Ridge National Laboratory, Oak Ridge, TN

Radiative Heat Transfer Under Transient Conditions

ORNL/Sub-84/89634/1 (1985, October)

A theoretical model for transient radiative heat transfer through low-density fibrous or particulate insulation is discussed. Calculations are reported for the ratio of scattered to total radiation when one boundary of a region at constant temperature undergoes an instantaneous temperature increase. The scattered radiation does not transfer energy to the insulation and exceeds 10% of the total radiation for fiber diameters less than about 4 um at low density. Calculations for spherical particles at low density also show scattered radiation exceeding 10% of total radiation for diameters less than about 7 um. The scattered fraction of initial radiative transfer is negligible in both cases for fractional densities greater than 0.03.

309

Klems, J.H., Lawrence Berkeley Laboratory, Berkeley, CA

Toward Accurate Prediction of Comparative Fenestration Performance

LBL-19550; 26 pp.; EEB-W-85-08; CONF-850237; Measuring Thermal Performance Characteristics of Windows, Proceedings of an International Workshop, Gaithersburg, MD, February 26, 1985 (1985, April)

The importance of going beyond laboratory measurements to prediction of field performance of fenestration systems is noted. The current state of the art in energy prediction related to fenestrations is discussed; a critique of the ASHRAE U-value is presented, and current questions about film coefficients are put into context. Ambiguities in the modeling of complex glazing systems are pointed out. Several questions about the convective processes in simple enclosures are raised, and the importance and uncertainty of solar gain calculations is underlined. It is concluded that accurate field measurements are needed to inform the predictive enterprise. A facility to make these measurements is described and current progress on calibrating this facility is presented.

310
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Measured Net Energy Performance of Single Glazing Under Realistic Conditions

LBL-20346; 10 pp.; CONF-851202; Thermal Performance of the Exterior Envelopes of Buildings - III, Proceedings of the DOE-ORNL-ASHRAE-BTECC Conference, Clearwater Beach, FL, December 2, 1985, 1421 pp. (1986, January)

A new measuring facility, the MoWiTT, has begun operation with a study of the summer performance of single glazing in south-facing and east-facing orientations. These measurements demonstrated the MoWiTT's capabilities and provided a baseline for future measurements of more complex fenestration systems. The net heat flow through the fenestration was measured at fifteen-minute intervals over several days. Simultaneous measurements of air temperatures and solar intensities were used as input data for an ASHRAE calculation of the same quantity, assuming standard summer values for the film coefficients. Good agreement between measured and calculated heat flows was obtained when the vertical surface solar intensity was used as input and the calculation included the effects of window setback.

311
Klems, J.H., and H. Keller, Lawrence Berkeley Laboratory, Berkeley, CA

Thermal Performance Measurements of Sealed Insulating Glass Units with Low-E Coatings Using the MoWiTT Field-Test Facility

LBL-21583; 15 pp.; CONF-870101; Proceedings of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers Meeting, New York, NY, January 18-21, 1987; ASHRAE Transactions 93(1) (1986, December)

Using data obtained in a mobile field-test facility, measured performance of clear and low-emissivity and double-glazing units is presented for south-facing and north-facing orientations. The changes in U-value and shading coefficient resulting from addition of the low-E coating are found to agree with theoretical expectations for the cold spring test conditions. Accurate nighttime U-values were derived from the data and found to agree with calculations. Expected correlation between U-value and wind speed was not observed in the data; a plausible experimental reason for this is advanced.

312
Klems, J.H., and H. Keller, Lawrence Berkeley Laboratory, Berkeley, CA

Measurement of Single and Double Glazing Thermal Performance Under Realistic Conditions Using the Mobile Window Thermal Tests (MoWiTT) Facility

LBL-22149; 11 pp.; CONF-870307; Solar Energy, Proceedings of the ASME/JSME/ISES Conference, Honolulu, HI, March 22-27, 1987 (1987, November)

The thermal performance of single glazing, clear double glazing, and double glazing with a low-emissivity coating was measured in both south-facing and north-facing orientations under realistic field conditions using the new MoWiTT field test facility. The time-dependent net heat flow through each fenestration was found to be consistent with the prediction of the standard simplified heat transfer model, provided that an angle-dependent shading coefficient is used and diffuse solar gain is included in the calculation. Summer-condition average U-values were derived for each glazing type and were found to agree with the expected values for both types of double glazing. The measured U-value for single glazing was lower than predicted.

313
Kolb, J.O., Oak Ridge National Laboratory, Oak Ridge, TN

Infiltration Testing of Homes Constructed to the BPA Model Conservation Standards Program

CONF-880814; Energy Efficiency in Buildings, Proceedings of a Summer Study, Pacific Grove, CA, August 28-September 3, 1988; (14 pp.) (1988, June)

The Bonneville Model Conservation Standards (MCS) requires air sealing techniques to reduce incidental infiltration in homes below levels found using conventional construction techniques. Measurements of infiltration in MCS code for instructed home are reported in this paper using two techniques: (1) blower door depressurization and short-term tracer gas decay to measure incidental infiltration; and (2) total infiltration with an air-to-air heat exchange operating.

314
Kolb, J.O., Oak Ridge National Laboratory, Oak Ridge, TN

Resources for O/M Training and Services in the Commercial Building Sector

ORNL/CON-204; 42 pp. (1988, April)

Within many commercial buildings, the most economical Energy Conservation Opportunities (ECO's) result from improved O/M of HVAC systems and building envelopes, yielding average energy and cost savings of 20% with paybacks of one year or less. Yet, in many such buildings, the improved O/M ECO is not being implemented by building owners and/or occupants. This report presents the results of a study of: (1) the scope and nature of resources for training and services in commercial building O/M, (2) the types of barriers that reduce the application of appropriate O/M procedures, and (3) the potential for increased penetration of O/M services. The study determined that there is a plethora of O/M training and service organizations in existence with a wide range of technical expertise and coverage of commercial building O/M as an ECO. Barriers to the application of improved O/M procedures, obtained from a wide range of industry sources, are presented and general recommendations for stimulating improved O/M procedures in commercial buildings include: (1) documentation of energy and cost savings and economic paybacks from actual O/M procedures, (2) strategic market development for O/M services through existing public and private organizations, and (3) methods to improve O/M training and building operators and service personnel.

315
Kolb, J.O., and M.S. Hubbard, Oak Ridge National Laboratory, Oak Ridge, TN

A Review of Utility Conservation Programs for the Commercial Building Sector

ORNL/CON-220; 102 pp. (1988, January)

This report presents the results of a survey of conservation program activities conducted by 26 public utilities in the commercial building sector. The purpose of the survey was to provide an information data base on utility-sponsored conservation programs planned or in progress for the commercial building sector. This data base is to be used by the Department of Energy (DOE) to define conservation programs that assist and complement utility conservation programs. Information on four types of conservation programs was solicited: (1) financial incentive programs, (2) energy service programs, (3) rate research and incentive programs, and (4) case studies and demonstration studies. The approach used in selecting the utilities to be surveyed is described. The results of the utility survey are summarized in terms of the following characteristics: (1) type of program, (2) program history, (3) marketing strategies, (4) program motivation, (5) system load effects and goals, and (6) evaluation activities, active or planned.

316
Kula, H.J., and H.E. Feustel, Lawrence Berkeley Laboratory, Berkeley, CA

Review of Wind Pressure Distribution as Input Data for Infiltration Models

LBL-23886; 41 pp. (1988, December)

Previous investigations have shown that the pressure difference between the inside and outside of the building is one of the driving forces for air infiltration. This pressure difference mainly depends on the wind and its interaction with the envelope of the building which is commonly expressed as dimensionless pressure coefficients.

The main part of this report is a literature review on the wind pressure distribution around the building, with emphasis on high-rise buildings. Reports of single family buildings were also reviewed and evaluated. In the second part of this paper, an examination wind pressure distribution curves on the centerline of the windward and leewardside of the building was done and a polynomial fit is presented. This set of coefficients covers a wide range of buildings of varying heights and varying plan area densities.

317
Kweller, E.R., National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Laboratory Tests of a Gas Fueled Modulating Type Hot Water Boiler

NBSIR-85-3142 (1985, April)

318
Lampert, O., Lawrence Berkeley Laboratory, Berkeley, CA

Chemical and Optical Properties of Electrochromic Nickel Oxide Films

LBL-20211 (1985, August)

Thin films of nickel oxide-nickel hydroxide are investigated to determine electrochromic switching properties. Crystalline nickel oxide films are synthesized by electrochemical deposition and by anodization of nickel electrodes. Electrochemical deposition using nickel sulfate-based chemistry is used to deposit films directly on doped tin oxide-coated glass. Spectral solar transmittance is obtained for films switched in liquid cells containing a KCH electrolyte. The solar transmittance (Ta) can be switched from Ta (bleached) 0.73 to Ta (colored) 0.35 for films with thickness of about 500 A. Voltammetric data is correlated to known electrochemical processes for nickel electrodes. The nickel oxide films are chemically analyzed using a sputter-Auger microprobe and x-ray photoelectron spectroscopy. As a result of combined analysis, it was determined that these films transform from uncolored to colored states by the reversible transformation of nickel hydroxide N1(CH)2 to nickel oxyhydroxide NiCOH and that dehydrated films correspond chemically to NiO.

319
Larson, S.C., and M.G. Van Geem, Construction Technology Laboratories, Inc., Skokie, IL

Heat Transfer Characteristics of Walls with Similar Thermal Resistance Values - Final Report

ORNL/Sub-79/42539/6; 151 pp. (1986, June)

Heat transfer characteristics of building elements must be known to evaluate energy losses through a building envelope. Laboratory tests of walls for dynamic outdoor temperature conditions provide data that can be used to determine thermal properties. Dynamic testing is particularly important for massive envelope components that store as well as transmit heat. A normal weight concrete wall with board insulation on the outdoor surface was tested in the calibrated hot box facility at the Construction Technology Laboratories, a division of the Portland Cement Association. The wall consisted of 8 in. (200 mm) of normal weight concrete with 5/8-in. (16-mm) polyisocyanurate board insulation bonded to the outdoor surface.

320
Larson, S.C., and M.G. Van Geem, Oak Ridge National Laboratory, Oak Ridge, TN

Surface Temperature Measurement Techniques for a Calibrated Hot Box Test Specimen

ORNL/Sub-79/42539/7; 78 pp. (1986)

Heat flow through a 143 pcf (2290 kg/cu m) normal weight concrete wall was measured using the calibrated hot box facility at the Construction Technology Laboratories, a division of the Portland Cement Association. Two methods of measuring specimen surface temperatures were used to investigate thermal contact resistance between thermocouples and a normal weight concrete specimen. In this test program, thermocouples were embedded in wall surfaces.

The wall was subjected to steady-state, transient, and periodically varying temperature conditions. Steady-state results are used to determine concrete thermal conductivity and wall resistance. Data obtained during transient and periodic temperature variations are used to define dynamic thermal response of the wall.

321
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Structural Thermal Break Systems for Buildings: Feasibility Study - Final Report

ORNL/Sub-84/21006/1; 102 pp. (1987, March)

This report presents results from the first phase of a program to investigate lightweight concrete systems for potential use as structural thermal breaks in buildings. The primary objective of the project is to develop a portland cement concrete with sufficient thermal resistance and strength properties to serve as an effective structural thermal break in building envelopes. Desirable properties of the proposed concrete are a density of less than 50 pcf (800 kg/cu m), a compressive strength of 1000 to 1500 psi (6.9 to 10.3 MPa), and a thermal conductivity of less than 1.5 Btu/in./hr/sq ft/F (0.22 W/m/K). The first phase of work, presented in this report, is a feasibility study to identify uses for the lightweight portland cement concrete. The report is subdivided into three sections. Section 1 presents suggested assemblies where lightweight concrete can be used in place of steel, other metal, or normal weight concrete to prevent thermal bridges or thermal bypasses. Potential uses for the proposed lightweight concrete include exterior walls, interior walls, columns, chimneys, foundations, and floor slabs. Thermal conductivity of the proposed lightweight concrete is approximately 1/10th that of normal weight concrete and 1/100th that of steel.

322
Lawrence Berkeley Laboratory, Berkeley, CA

Building Ventilation and Indoor Air Quality Program - 1984

LBL-18753; 104 pp. (1985, September)

323
Lawrence Berkeley Laboratory, Berkeley, CA

Indoor Environment Program - FY 1987 Annual Report

LBL-24216; 41 pp. (1988, March)

LBL is a major center of building science research. An important part of that research is the environment defined by the building, the major focus of the work of the Indoor Environment Program. The Program examines the scientific issues associated with the design and operation of buildings to optimize building energy performance and occupant comfort and health. Optimizing health and comfort of occupants is addressed in different ways by the groups that comprise the Program. The Energy Performance of Buildings Group examines energy flow through all elements of the building shell. It measures air infiltration rates, studies thermal characteristics of structural elements, and develops models of the behavior of complete buildings. The potential for savings in the infiltration area is great. The heat load associated with natural infiltration is about 2.5 quads/yr costing about $15 billion annually. It may be economic to reduce this by 25%.

324
Lee, A.D., and R.G. Pratt, Pacific Northwest Laboratory, Richland, WA

Development and Implications of a Software-Based Residential Energy Conservation Standard

PNL-SA-13866; 15 pp.; CONF-8604290; Proceedings of a Joint National Meeting of ORSA/TIMS, Philadelphia, PA, April 4, 1986 (1986, November)

Development and implications of the Federal Residential Conservation Standard, uniquely software-based, are described and discussed. By law, the Department of Energy is required to develop and issue energy conservation performance standards for residential buildings. Federal agencies that produce housing will implement the standard. The objectives for the standard were to: (1) provide performance-based requirements, (2) use cost-effectiveness criteria, (3) accommodate local and changing conditions, and (4) maximize ease of use. The program is described and samples of its output are illustrated, and issues related to the acceptability of a software-based standard are discussed. Public review and comment should help reveal and evaluate advantages, disadvantages, and potential problems of using a software format for standards, and should help assess the potential for software-based standards in the private sector.

325
Levins, W.P., and M.A. Karnitz, Oak Ridge National Laboratory, Oak Ridge, TN

Energy Measurements of Attic Radiant Barriers Installed in Single-Family Houses

CONF-880814; Energy Efficiency in Buildings, Proceedings of a Summer Study, Pacific Grove, CA, August 28-September 3, 1988; (11 pp.) (1988, July)

Testing was conducted by the Oak Ridge National Laboratory to determine the energy savings attributable to radiant barriers installed in attics of unoccupied single-family houses. Three levels of fiberglass attic insulation (R-11, R-19, and R-30) were tested with two types of barrier installation (horizontal and truss). The results showed that horizontally installed radiant barriers were more effective than other barriers in reducing heating and cooling loads. Measured cooling load reductions ranged from 0 to 22% (compared to same attic insulation R-value with no radiant barrier) and heating load changes from plus 4% to -10% were measured (compared to same attic insulation R-value with no radiant barrier).

326
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Heating Energy Measurements of Unoccupied Single-Family Houses with Attics Containing Radiant Barriers

ORNL/CON-213; 80 pp. (1987, January)

Tests were conducted by Oak Ridge National Laboratory (ORNL) to determine the magnitude of the heating energy savings achieved by installing attic radiant barriers. The radiant barriers used for the test consist of a material with two reflective aluminum surfaces on a kraft paper base. The experiment was conducted in three unoccupied research houses operated by ORNL. Two variations in the installation of radiant barriers were studied. One house was used as the control house (no barrier was installed), while the other two were used to test the two methods for installing the radiant barriers. In one house, the radiant barrier was laid on top of the attic fiberglass batt insulation, and in the other house, the barrier was attached to the underside of the roof trusses. The attics of all three houses were insulated with a kraft-paper-faced R-19 fiberglass batt insulation. The winter test with the radiant barrier showed that the horizontal barrier was able to save space-heating electrical energy in both the resistance and heat pump modes amounting to 10.1% and 8.5%, respectively. The roof truss radiant barrier increased consumption by 2.6% in the resistance mode and 4.0% in the heat pump mode. The horizontal orientation of the radiant barrier is the more energy-effective method of installation.

327
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Heating Energy Measurements of Single-Family Houses with Attics Containing Radiant Barriers in Combination with R-11 and R-30 Ceiling Insulation

ORNL/CON-239; 97 pp. (1988, August)

Tests were conducted by Oak Ridge National Laboratory to determine the heating energy performance to two levels of fiberglass-batt attic insulation (R-11 and R-30) in combination with truss and horizontally installed radiant barriers. The tests, a continuation of work started in the summer of 1985, were conducted in three unoccupied ranch-style houses in Karns, Tennessee, during the winter of 1986-87. The measured results of the heating tests showed that a horizontal radiant barrier used with R-11 attic insulation reduced the house heating load by 9.3% compared with R-11 with no radiant barrier, while a truss barrier showed essentially no change in the heating load.

328
Levy, M.E., and R. Jones, New York State Energy Research and Development Authority; Brookhaven National Laboratory, Upton, NY

An Agenda For Cooperative R and D in Advanced Energy - Efficient Housing: Final Report

NYSERDA-88-4; 66 pp. (1988, February)

Relative to its size in the national economy, the home building sector and related organizations conduct little research and development. Yet, many of the problems that face the industry today, and are expected to confront the industry in the future, and many of the opportunities for creating a more vibrant and intentionally competitive industry, are inextricably linked to a strong R and D agenda. This study continues the much-needed process of identifying the logical role for public agencies in conducting and promoting energy-related housing research. Research needs, according to authors, must be illuminated against the back-drop of a housing industry undergoing changes that may fundamentally alter the way homes are built, regulated, financed, and marketed. This study concludes that in order for housing to evolve in ways that are responsive to the problems the housing industry faces today and those that are anticipated in the future, a well-planned and well-coordinated program of publicly supported R and D is essential.

329
Li, F., R. Verderber, D. Hollister, and S. Berman, Lawrence Berkeley Laboratory, Berkeley, CA

Improvement of the Efficacy of Fluorescent Lamps by Isotope Blending

LBL-21828 (1986, June)

330
Lippiatt, B.C., S.F. Weber, and R.T. Ruegg, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Energy Prices and Discount Factors for Life-Cycle Cost Analysis: Annual Supplement to NBS Handbook 135 and NBS Special Publication 709 - 1985 Edition

NBSIR-85-3273; 97 pp. (1985, November)

The report provides the 1985 annual edition of the energy-price and discount-factor tables used to supplement both the federal life-cycle costing methodology as described in NBS Handbook 135 (HB 135) and private sector life-cycle cost analysis as described as described in NBS Special Publication 709 (SP 709). Tables A (7%), Ba, and C represent revisions of Appendices A, B, and C, respectively, of HB 135. They should be used in life-cycle cost analyses of federal energy-conservation projects. Tables A (10%), Bb, and C are to be used in life-cycle cost analyses of federal non-energy conservation projects that require energy-price forecasts. The last section of the report, the supplement for private sector life-cycle cost analysis, is identical to Appendix B, Part I of SP 709 and is provided for the convenience of private sector analysts wishing to make use of federal energy-price forecasts.

331
Litvin, A., and M.G. Van Geem

Structural Thermal Break Systems for Buildings Development and Properties of Concrete Systems

ORNL/Sub-84/21006/2; 91 pp. (1988)

This report presents results from the second phase of a three phase program to investigate lightweight concrete systems for potential use as structural thermal breaks in buildings. The primary objective of the project is to develop a portland cement concrete with sufficient thermal resistance and strength properties to serve as an effective structural thermal break in building envelopes. Desirable properties of the proposed concrete are a density of less than 50 pcf (800 kg/cu m), a compressive strength of 1000 to 1500 psi (6.9 to 10.3 MPa), and a thermal conductivity of about 1.5 Btu/in./hr/sq ft/deg F (0.22 W/m-K). The second phase of work, presented in this report, is the laboratory development and measurement of properties of the lightweight portland cement concrete. The portland cement concrete developed for this project can be used to combine structural, thermal insulation, and heat storage capacity functions of exterior walls in one element. For many climates, this concrete can be used without additional insulation as a complete wall system in low-rise buildings.

332
Loss, W., Brookhaven National Laboratory, Upton, NY

Metal Buildings Study: Performance of Materials and Field Validation

BNL-52134; 73 pp. (1987, December)

A 5000 square-foot metal building located at Brookhaven National Laboratory has been monitored over a winter season. Air infiltration was measured using perfluorocarbon tracers, and heat loss was calculated. Slab lasses and effect of thermal bridges was assessed.

333
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BTESM National Program: Past, Present, and Future

ASHRAE-SP-49; CONF-851202; Thermal Performance of the Exterior Envelopes of Buildings - III, Proceedings of the DOE-ORNL-ASHRAE-BTECC Conference, Clearwater Beach, FL, December 2, 1985, 1421 pp.; (pp. 1146-1149) (1986)

This paper reviews some of the history of the National Program for Building Thermal Envelope Systems and Materials (BTESM) indicating key decisions for important components of the program including such things as creation of the Building Thermal Envelope Coordinating Council (BTECC) and implementation of this series of conferences involving ASHRAE (and now BTECC) as joint sponsors with DOE. Formalized technology transfer activities, including the holding of institutes for architectural and engineering faculty members, and student design competitions, and one of several informal person-to-person networks of technical information sharing within the total building community are described.

334
Macal, C.M., M.J. Bragen, and J.E. Marshal, Argonne National Laboratory, Argonne, IL; Illinois Department of Natural Resources, Springfield, IL

An Integrated Energy Planning Model for Illinois

Energy 12(12):1239 (1987)

An integrated energy supply-and-demand model for the state of Illinois is described. This equilibrium model is an important tool for integrating information from a variety of planning studies and data bases. A wide range of energy issues affecting diverse areas of the energy system, such as Illinois coal production under alternate oil price assumptions, renewable energy resource potential, and conservation options, can be analyzed by using the model.

335
MacDonald, J.M., and M.B. Gettings, Oak Ridge National Laboratory, Oak Ridge, TN

Military EMS (Energy Monitoring and Control Systems): Implications for Utilities, Cities, and Energy Services

CONF-880814; Energy Efficiency in Buildings, Proceedings of a Summer Study, Pacific Grove, CA, August 28-September 3, 1988; (11 pp.) (1988, July)

Possible extensions of energy monitoring and control systems to a high level control for buildings over large areas is discussed. An overview of factors that have an impact for the large scale EMCS concept, limited trend data available on energy and cast savings for the military systems was evaluated, operational and maintenance considerations, that impact use of the large scale EMCS, a discussion of some implications for potential future use of large scale EMCS and recommendation for future work presented.

336

MacDonald, J.M., M.B. Gettings, D. Goldenberg, and D.M. Wasserman, Oak Ridge National Laboratory, Oak Ridge, TN

Evaluation, Modification, and Deployment of the ECOP-II Computer Program

ORNL/CON-248; 71 pp. (1988, March)

Evaluation and modification of the ECOP-II computer program and recommendations on the deployment of ECOP-II is included. The ECOP-II computer program (Energy Conservation Opportunity Program) for small commercial and lighting industries was developed under the direction of the U.S. Air Force. Results of the data gathering efforts at 11 military installations, reviews of algorithms and calculations, the validation analysis of ECOP-II, and recommendations for general use of ECOP-II, personnel requirements and related recommendations for energy management efforts at military bases are discussed.

337

MacDonald, J.M., M.A. Karnitz, R.C. Diamond, R.L. Ritschard, W.R. Mixon, and M.H. Sherman, Oak Ridge National Laboratory, Oak Ridge, TN

Existing Building Efficiency Research - 1987-1988: Research Update

ORNL/CON-268; 57 pp. (1988, August)

This Research Update presents the status of the Existing Building Efficiency Research Program of the Office of Buildings and Community Systems of the U.S. Department of Energy for the period 1987-1988. This program covers research on energy efficiency improvements for the residential and commercial buildings in this country. Improving energy efficiency of existing buildings through retrofit measures offers the largest potential for energy savings in the next 10 to 15 years in the United States. The program is working to overcome the technical, financial, and behavioral barriers to the use of building energy retrofits.

338

MacDonald, J.M., H.P. Misuriello, D. Goldenberg, M.P. Ternes, and J.O. Kolb, Oak Ridge National Laboratory, Oak Ridge, TN; W.S. Fleming and Associates, Inc., Washington, DC; EnerServ, Inc., Oak Ridge, TN

Commercial Retrofit Research for Multi-Year Plan - FY 1986-FY 1991: Building Energy Retrofit Research

ORNL/CON-218; 52 pp. (1986, October)

This Multi-Year Plan details a framework for a coordinated national research and development (R and D) program aimed at improving the effectiveness of public and private efforts to conserve energy in the existing commercial building sector. It summarizes the project areas determined to be most important to the goal of achieving the energy savings potential in commercial buildings. It is the first multi-year plan detailing energy conservation R and D efforts directed specifically toward retrofits in the commercial sector. This plan was developed by the Department of Energy's (DOE) Office of Buildings and Community Systems through the combined efforts of the Oak Ridge National Laboratory and other government and private organizations.

339

Macriss, R.A., and T.S. Zawacki, Institute of Gas Technology, Chicago, IL

Worldwide Survey of Absorption Fluids Data

CONF-8804100; Research and Development on the Heat Pump for Space Conditioning

Applications, Proceedings of the Second DOE/ORNL Heat Pump Conference, Washington, DC, April 17-20, 1988, 225 pp.; (7 pp.) (1988)

The objective of this study is to develop improved data for the thermodynamic, transport and physical properties of absorption fluids. A specific objective of this phase of the study is to compile, catalog and coarse-screen the available worldwide data of known absorption fluid systems and publish it as a reference document to be distributed to manufacturers, researchers and others active in absorption heat pump activities.

340
Mahajan, B.M., National Bureau of Standards, Washington, DC

Energy Rating of Refrigerators with Variable Defrost Controls

ASHRAE Transactions (3133):330 (1988, January)

This paper deals with refrigerator-freezers and freezers that are equipped with variable defrost control (VDC) systems. The modified long-time automatic defrost test procedure and the procedure to calculate per day (or test cycle) energy consumption for machines equipped with VDC are examined. The effects of compressor run-time between defrosts (CT) on per day energy consumption are evaluated, and a procedure for computing a generic value of CT is suggested.

341
Marsala, J., E.P. Whitlow, and B.A. Phillips, Oak Ridge National Laboratory, Oak Ridge, TN

Development of a Residential Gas-Fired Absorption Heat Pump-Component Development - Field Trial Program

ORNL/Sub-79/24610/3 (1986, May)

This is the third report of the series on the development of absorption-type, gas-fired heat pumps using organic working fluids. The residential heat pumps were to provide the full heating and cooling requirements of a house down to 0 deg F outdoor temperature. The subject matter of this volume concerns the design, construction, development and testing of early units for an outdoor field trial under both residential use and in continuous run operation outdoors. Simultaneously, those components of the heat pump system which had not attained full performance levels, i.e. components of the sealed absorption system and auxiliary components, were developed individually on breadboard test units to attain the design requirements for full performance. Six absorption heat pumps using R-133a and ETFE as the working fluids were designed, constructed, developed and tested as part of the field trial.

342
Martin, P.C., and J.D. Verschoor, Manville Service Corporation, Denver, CO

Investigation of Dynamic Latent Heat Storage Effects of Building Construction and Furnishing Material

ORNL/Sub-86/22016/1; 82 pp. (1986, August)

This investigation was conducted to develop primary data on the dynamic moisture response of selected building construction and furnishing materials subjected to cyclical changes in relative humidity at constant temperature. The cyclical changes in relative humidity were to simulate daytime air-conditioning followed by nighttime ventilation with cool but humid outside air. The data obtained will be useful for modeling and comparing the energy efficiency of different building operating schemes. Testing was performed on fifteen different commercial construction and furnishing materials in a controlled temperature and humidity chamber. The materials were subjected to three different dynamic daily humidity cycles of at least two weeks duration and to four different constant humidity exposures of up to two weeks each. Weight changes of the materials, as they gained or lost moisture, were monitored by sensitive load cells.

343
Matthews, T.G., Oak Ridge National

Laboratory, Oak Ridge, TN

A Brief Review of Control Measures for Indoor Formaldehyde

CONF-880382; Indoor Environmental Controls and Lung Disease, Proceedings of the American Thoracic Society Workshop, Santa Fe, NM, March 24, 1988; (5 pp.) (1988)

The indoor environment contains a variety of consumer and construction products that emit formaldehyde vapor. This paper summarizes the effectiveness of post-installation control measures, product aging, installations of permeation barriers (i.e., flooring), and increased building ventilation.

344
Mattingly, G.E., National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

A Report on the NBS-DOE May 1984 Workshop on Thermal Metering

NBSIR-85-3242 (1985, November)

345
Mattingly, G.E., T.T. Yeh, and B. Robertson, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Flow Meter Installation Effects: A New Approach to an Old But Prevalent Problem

(1986, June)

346
May, W.B., and G.E. Kelly, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Verification of Public Domain Control Algorithms for Building Energy Management and Control Systems

NBSIR-85-3285; PB-86-237104/XAB; 142 pp. (1985, December)

Software is an important component of building energy management and control systems (EMCS). The National Bureau of Standards developed and documented eight public-domain EMCS supervisory control algorithms. The testing and verification of these eight algorithms are described in the report. The algorithms tested cover dry-bulb and enthalpy-economizer cycles, optimum and scheduled start/stop, duty cycling, demand limiting, outside air supply air reset, and demand supply air reset.

347
May, W.B., and C. Park, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Building Emulation Computer Program for Testing of Energy Management and Control System Algorithms

NBSIR-85-3291; PB-86-163821/XAB; 133 pp. (1985, December)

A building emulator can be used to test energy management and control systems (EMCS). The emulator uses a computer program to simulate the responses of a building including the equipment, building space, and building envelope to EMCS commands. Building model software for the emulator has been developed at the National Bureau of Standards (NBS) in an effort to assist the United States Naval Civil Engineering Laboratory (NCEL), which is developing a sophisticated building emulator. The concept of the building emulator and the building emulator computer program are described in this report. The program includes the weather, the air handling unit, the zone, and the comfort model. In addition, the energy compilation routine is also included. The models presented here are simplified models. With these abridged models, a single zone building with exterior walls and a single deck air handling unit are simulated. A complete FORTRAN source code of the building emulator computer program is appended.

348
Maya, J., Lawrence Berkeley Laboratory, Berkeley, CA; GTE Lighting Products,

Danvers, MA

Test, Evaluation, and Report on Mercury Enrichment for Fluorescent Lamps

LBL-20614; 57 pp. (1985, November)

This report summarizes results of fluorescent lamp studies carried out during the time period January 1, 1984 to December 31, 1984 by GTE Products corporation for the DOE under a subcontract from Lawrence Berkeley Laboratories. The studies are divided into the following four areas: Magnetic Field Effects, Lamp Isotope Experiments, Modeling of Isotope Effects, and ZWHg Isotope Separation in a Flow Reactor.

349
Mazzucchi, R.P., Pacific Northwest Laboratory, Richland, WA

End-Use Loads in Restaurants

PNL-SA-13531 (1985, November)

350
McCann, J., L. Horn, J.R. Girman, and A.V. Nero, Lawrence Berkeley Laboratory, Berkeley, CA

Potential Risks from Exposure to Organic Carcinogens in Indoor Air

LBL-22474; 31 pp.; CONF-8610446; Application of Short-Term Bioassays in the Analysis of Complex Environmental Mixtures, Proceedings of an EPA Symposium, Durham, NC, October 20-23, 1986 (1986, October)

We have examined the current literature reporting concentrations of organics in indoor environments to construct a nominal list of indoor air concentrations for 140 compounds. We have gone on to examine, in a preliminary way, the potential risk of various health endpoints from indoor air exposure to these substances. An important component of this study has been to examine risks for the carcinogens among these substances. We report our preliminary assessment of cancer risks from exposure to 24 carcinogens, using several analytical approaches.

351
McCarty, K.S., and A. Wilmer

Home Energy Rating Systems: Purposes, Operations, Barriers, and Future Research Needs

(1985, January)

352
McCold, L.N., Oak Ridge National Laboratory, Oak Ridge, TN

Field Test Evaluation of Conservation Retrofits of Low-Income, Single-Family Buildings: Combined Building Shell and Heating System Retrofit Audit

ORNL/CON-228/P3; 66 pp. (1987, May)

DOE asked ORNL to devise a procedure for selecting an optimum combination of building shell and heating system retrofits for single-family dwellings. To determine the best retrofits for each house that would maximize program savings, ORNL staff members developed an approach that used information from a preretrofit energy audit of candidate houses. Audit results are used to estimate annual energy savings for various retrofits for each house. Life-cycle benefits (B) are calculated, as are the estimated installation costs (C) for given retrofits in given houses. The benefits-to-cost ratios (B/Cs) are then ranked for all possible retrofits to all candidate houses, and the top-ranking B/C retrofits are selected for installation. This process maximizes program savings, and it is adaptable to varied housing types in different climates. The Audit-Directed Retrofit Program (ADRP) was field tested in a low-income housing retrofit program in Wisconsin during the winter of 1985-86. Results of the field test are reported in a companion document. This report describes the ADRP for the benefit of potential users.

353
McCold, L.N., Oak Ridge National Laboratory, Oak Ridge, TN

A Retrofit Audit for Residential Building Shell and Space Heating Systems

ORNL/TM-9974 (1986, September)

354
McCold, L.N., and N.S. Bishop, Oak Ridge National Laboratory, Oak Ridge, TN

Measurement and Analysis of Domestic Hot Water Loads of Three Navy Buildings at Memphis Naval Air Station, Millington, Tennessee: Implications for Decentralized Small Cogeneration

ORNL/TM-9623; 81 pp. (1986, August)

Decentralized small cogeneration is the use of cogeneration equipment with electric generating capacities less than 500 kW at individual buildings or building complexes served by a common mechanical equipment room. Cogenerated heat could be used in Navy buildings for space heating, space cooling, or domestic water heating. In most climates, production of domestic hot water is the best use for cogenerated heat because it is needed virtually every day of the year. The Navy initiated this study because information on domestic hot water usage in Navy buildings was either non-existent or of insufficient quality and reliability to confidently design a small cogeneration installation. Hourly domestic hot water data were measured by a flow meter and temperature sensors and recorded by an electronic data logger. The data were plotted to display their characteristics, and they were analyzed with a simple heat storage model to examine the effects of heat storage on the utilization and proper sizing of a cogeneration system.

355
McCold, L.N., J.A. Schlegel, and D.C. Hewitt, Oak Ridge National Laboratory, Oak Ridge, TN; Wisconsin Energy Conservation Service, Madison, WI

Technical and Practical Problems at Developing and Implementing an Improved Retrofit Audit - Final Report

CONF-860818; Energy Efficiency in Buildings, Proceedings of the American Council for an Energy Efficient Economy Santa Cruz Summer Study, Santa Cruz, CA, August 17, 1986; (15 pp.) (1986)

Oak Ridge National Laboratory developed a retrofit audit suitable for use in Low-Income Weatherization Assistant Program. The audit was field tested the winter of 1986 on 35 single-family houses in Wisconsin. Important technical problems encountered in developing and implementing an accurate audit is described. The paper discusses the various types of research needed and focuses attention on the issues.

356
McCold, L.N., J.A. Schlegel, L.A. O'Leary, and D.C. Hewitt, Oak Ridge National Laboratory, Oak Ridge, TN

Field Test Evaluation of Conservation Retrofits of Low-Income Single-Family Buildings in Wisconsin: Audit Field Test - Implementation and Results

ORNL/CON-228/P2; 77 pp. (1988, June)

This report describes the field test of a retrofit audit. The field test was performed during winter of 1985-86 in four south central Wisconsin counties. The purpose of this report is to describe methods and results of the field test.

357
McDonald, R.J., and J.D. Nally, Brookhaven National Laboratory, Upton, NY

Technical Assessment of a Direct Contact Heat Exchanger as an Energy Conservation Retrofit Option

BNL-51978; 82 pp. (1985, December)

The objective of this report is to present the results of an engineering analysis of the energy conservation potential of a direct contact heat recovery process applied to residential sized warm air furnaces. A laboratory study was conducted using both a gas-fired furnace and an oil-fired furnace. A series of measurements were performed to measure various parameters associated with the test furnaces, both in a baseline condition and with direct contact heat exchangers added to the systems.

358
McElroy, D.L., F.J. Weaver, D.W. Yarbrough, and R.S. Graves, Oak Ridge National Laboratory, Oak Ridge, TN

The Thermal Resistance of Fine Powders at Atmospheric Pressure and Under Vacuum

CONF-871203; Insulation Materials, Testing and Applications, Proceedings of the 1987 Conference, Bal Harbour, FL, December 6, 1987; (29 pp.) (1987)

Heat transport measurements are reported on candidate insulation systems with relatively high thermal resistances for use in applicances. The thermal resistances of small diameter silica powders at atmospheric pressure and under vacuum were measured from 295 to 340 K using unguarded radial heat flow techniques. The thermal resistances of rectangular panels containing perlite or silica powder at reduced pressure were determined using an unguarded linear heat flow technique. Values of 1.2 sq m X K/W for 0.0254 m (R-7 per inch) were obtained at atmospheric pressure for powders of pure, fumed, amorphous 0.01 um dia silica particles compacted to about 10% of theoretical density.

359
McLain, H.A., D. Goldenberg, M.A. Karnitz, S.D. Anderson, and S.Y. Ohr, Oak Ridge National Laboratory, Oak Ridge, TN; EnerServ, Inc., Oak Ridge, TN

Benefits of Replacing Residential Central Air Conditioning Systems

ORNL/CON-113; 71 pp. (1985, April)

The energy efficiency ratios (EERs) of marketed residential air conditioning equipment have increased during recent years. This investigation examined the benefits of replacing a unit having an EER of 6 with a unit having an EER of 10 in a prototypical two-story house located in each of 32 cities in the United States. The U.S. Department of Energy building simulation model, DOE-2.1A, was used to predict the energy savings associated with this action. The reasonableness of the model for this study was confirmed by comparing the DOE-2.1A predicted energy use data with measured energy use data for the Tennessee Energy Conservation in Housing (TECH) control house in Knoxville, Tennessee, and four specially metered houses in Little Rock, Arkansas. It was predicted that the seasonal energy efficiency ratios (SEERs) of correctly sized units would vary from 0.6 of the rated EERs in the northern part of the country, to 0.8 of the rated EERs in the middle part of the country, and to about the rated EERs in the lower southern part of the country. Oversized units were predicted to have lower SEERs. These values reflect the total annual energy consumed by the air conditioning units, including the energy used by the crankcase heaters. From these results, a simplified Residential Conservation Service Model Audit procedure for estimating SEERs from EERs was developed.

360
McLain, H.A., J.M. MacDonald, and D.J. Downing, Oak Ridge National Laboratory, Oak Ridge, TN

An Analytical Investigation of Energy End-Use In Commercial Office Buildings

ORNL/CON-250; 186 pp. (1988, March)

Intended as a preliminary report, this study is to analyze the end-use energy behavior of commercial office buildings. Energy use data files were created using DOE-2.1 building simulation program weather data from Chicago, IL; Fortworth, TX; and Miami, FL. Analysis was completed for three different buildings located in the above mentioned cities. Results of the calculations performed, with analysis of their importance are presented in this report.

361
McLinden, M.O., and D.A. Didion, National Bureau of Standards, Washington, DC

Quest for Alternatives

ASHRAE Journal (1987)

The advent of an international agreement limiting production of certain refrigerants because of their detrimental effects on the atmosphere has caused concern in the refrigeration and air conditioning industry. Authors discuss tradeoffs and limitation in seeking refrigerants, and provide alternatives.

362
McMahon, J.E., Lawrence Berkeley Laboratory, Berkeley, CA

The LBL Residential Energy Model: An Improved Policy Analysis Tool

LBL-18622; Energy Systems Policy 10(1):41-72 (1987)

Energy consumption in residences accounts for 20% of total energy and 35% of electricity used in the United States today. Over time, the amount of energy consumed to provide a particular service will change. The mix of fuels consumed also changes; recently, households have increased their electricity consumption and decreased consumption of fossil fuels. For these reasons, an understanding of the components of residential energy consumption is important to utility companies and government policy makers. This article describes the development of the LBL Residential Energy Model to provide improved policy analysis at the end-use level. The major improvements include: representation of recent equipment efficiency trends; new techniques for forecasting future appliance efficiencies and annual appliance replacements; and extension of the model to include heat-pump space-conditioning systems. The resulting forecasts give improved agreement with recently reported energy consumption and provide lower estimates of future energy consumption.

363
McNall, P.E., National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

IAQ Modeling Workshop Report

NBSIR-85-3150 (1985, April)

364
McNall, P.E., G.N. Walton, S. Silberstein, J. Axley, and K. Ishiguro, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Indoor Air Quality Modeling Phase I Report - Framework for Development of General Models

NBSIR-85-3265; 65 pp. (1985, October)

The report presents a framework for the development of a model for predicting the indoor air pollutant concentrations in a variety of building types under practical conditions of weather, building occupancy, building construction, and pollutant source strength. The general concepts needed for developing an indoor air-quality model are treated. Examples of the current state of indoor air-quality models are given. The pollutants discussed are formaldehyde, radon, nitrogen oxides, tobacco smoke, particulates, carbon dioxide, and carbon monoxide.

365
Meal, M., M.A. Piette, and B.L. Gardiner, Lawrence Berkeley Laboratory, Berkeley, CA

Evaluating the Measured Results of Demand-Control Strategies in Commercial Buildings

LBL-19356; CONF-850606; Proceedings of the Semiannual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Honolulu, HI, June 23-26, 1985; ASHRAE Transactions 91(2B):961-974 (1985)

There has been little evidence that demand-control techniques have succeeded in reducing power demand, or that their implementation has been cost-effective. To fill this gap, the measured results of demand-control in new and retrofitted commercial buildings are being compiled. Various demand-control strategies and their impact on power and energy consumption, and a methodology for analyzing the measured performance of these demand-control strategies are described. Four performance indicators are developed and applied to 17 buildings that have implemented demand control. The limitations to using whole building data to evaluate peak power performance in the commercial sector are discussed.

366

Mei, V.C., Oak Ridge National Laboratory, Oak Ridge, TN

ORNL Ground Coil Analytical and Experimental Studies

CONF-841231; Research and Development on Heat Pumps for Space Conditioning Applications, Proceedings of the DOE/ORNL Heat Pump Conference, Washington, DC, December 10, 1984; (pp. 133-137) (1985, August)

A research program to understand the phenomenon of soil heat transfer coupled with fluid flow, soil moisture freezing, soil moisture migration, and ground surface temperature variations is described. From these studies, comprehensive ground coil mathematical models are being developed to better predict ground coil heat exchanger performance. The fundamental concept is to be more rigorous in the theoretical analyses underlying development of mathematical models for different types of ground coils. The resulting models are then validated with laboratory or field experimental results. Once validated, the models can be used to design the ground coil. The program has been loosely divided into three phases. Phase I was for ground coils involving heat transfer only, which was suitable for deep-well, tube-in-tube type ground heat exchanger analyses. Phase 2 is for ground coils involving heat transfer and soil moisture freezing, which are designed for horizontal ground coil winter operation. Phase 3 will be for ground coils involving heat transfer and soil moisture migration, which are designed for horizontal ground coil summer operation. The effect of ground surface temperature variation and thermal interference from the adjacent coil legs will be added to phases 2 and 3 at a later stage of the model development.

367

Mei, V.C., Oak Ridge National Laboratory, Oak Ridge, TN

Theoretical Heat Pump Ground Coil Analysis With Variable Ground Farfield Boundary Conditions

CONF-850810; Heat Transfer - Denver 1985, Proceedings of the 23rd National Conference, Denver, CO, August 4, 1985. American Institute of Chemical Engineers, New York, NY; (pp. 7-12) (1985)

The operation of a single ground coil is described in detail mathematically. The mathematical model includes the effects of ground seasonal temperature variation, and the effect of coil fluid properties and flow characteristics, generally ignored by the traditional line source theory approach. A computer code, based on the model, has been completed and validated satisfactorily by the field experimental results. A parametric study indicates that the coil length, coil burial depth and soil thermal conductivity are important factors in determining the ground coil performance. This computer code, one of the more advanced available so far, can be used for heat pump ground coil design if moisture migration is not a predominating factor in determining the soil thermal properties.

368

Mei, V.C., Oak Ridge National Laboratory, Oak Ridge, TN

Horizontal Ground-Coil Heat Exchanger Theoretical and Experimental Analysis

ORNL/CON-193; 130 pp. (1986, December)

Ground-coupled heat pump systems have long been recognized for their high potential for energy conservation. However, the design of the ground-coil heat exchanger is still largely based on line-source theory, which was developed for heat pump ground-coil application back in the 1940s. Three ground-coil models were developed: One incorporated a radially symmetrical temperature profile and a soil freezing effect around the coil; one include a three-dimensional ground temperature distribution caused by heat transfer between the ground surface and ambient air; and one contains ground heat transfer and thermal interference effects. All three models have been

validated with the field experimental data provided by Brookhaven National Laboratory and by The University of Tennessee. The maximum error in calculated energy exchange between coil and ground is less than 16%, on the conservative side, compared with the measured values. One section of this report includes a comparison of a line-source theory model, a modified line-source theory model, and (3) one of the ORNL models.

369
Mei, V.C., and C.J. Emerson, Oak Ridge National Laboratory, Oak Ridge, TN

New Approach for Analysis of Ground-Coil Design for Applied Heat Pump Systems

CONF-850606; Proceedings of the Semiannual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Honolulu, HI, June 23-26, 1985; ASHRAE Transactions 91(2B):1216-1226 (1985, June)

The operation of a single coil buried in moisture-saturated ground is described in detail mathematically. The mathematical model includes the effects of coil cyclic operation and soil moisture freezing round the coil. The effect of coil fluid properties and flow characteristics, generally ignored by most of the traditional analytical methods, are also included in the analysis. A computer code based on the model has been completed and partially validated by the field experimental results. A parametric study indicates that the fluid inlet temperature, coil size and material, fluid flow Reynolds number, and schedule of coil cyclic operation are important factors in determining ground coil performance. This computer code can be used for heat pump ground coil design if heating load is predominant.

370
Mei, V.C., and E.A. Nephew, Oak Ridge National Laboratory, Oak Ridge, TN

Life-Cycle Cost Analysis of Residential Heat Pumps and Alternative HVAC Systems

ORNL/TM-10449; 76 pp. (1987, September)

A simple methodology is presented for calculating the life-cycle cost of a residential heat pump, an electric furnace with a central air conditioner, and a gas furnace with a central air conditioner. The procedure described in this report involves application of the Annual Performance Factor computer model developed by the Oak Ridge National Laboratory. This model was used to calculate the annual energy consumption of each of the three systems for 117 different climatic locations within the United States for residential buildings of varying sizes and insulation levels. Nine example calculations are included in the report to better explain the calculational procedure. These examples show that the life-cycle costs of the residential heat pump are somewhat higher than those of the gas furnace with central air conditioner. However, the cost advantage of the gas-fired system is not decisive and could disappear in locations having low power costs or if relative fuel prices change.

371
Meier, A.K., J.F. Busch, and C.C. Conner, Lawrence Berkeley Laboratory, Berkeley, CA; Pacific Northwest Laboratory, Richland, WA

Testing the Accuracy of a Measurement-Based Building Energy Model with Synthetic Data

Energy and Buildings 12:77 (1988)

A new class of building energy models has emerged which use short-term measured data to predict energy performance for a longer period or for average conditions (such as "weather normalization"). Few of these models have been fully validated because tests are complex, and it is difficult to control all variables. A procedure to test the accuracy of one aspect of a measurement-based model is described and applied to a recently developed model. The model was found to yield significant errors in predicted annual space heating use, but revised algorithms greatly improved the model's accuracy.

372
Meier, A.K., and B. Nardman, Lawrence Berkeley Laboratory, Berkeley, CA

A Thermal Analysis of the Model

Conservation Standards for New Electrically-Heated Houses

Energy 13(11):833 (1988)

Energy-efficiency standards have been proposed for new, electrically-heated houses constructed in the Pacific Northwest. Before implementation, several hundred houses were built to the new standards in order to determine their cost-effectiveness. In order to estimate the energy savings, weekly energy consumption data for total utility, space heating, water heating, and appliances were collected for the houses built to the new standards and an equal number of Control houses. After adjustments for climate, floor area, internal gains, and inside temperature, the homes built to the new standard used about 45% less electrical space heat than the Control homes.

373
Melroy, W.J., and D.A. Didion, National Bureau of Standards, Washington, DC

Refrigerant Migration in a Split-Unit Air Conditioner

ASHRAE Transactions 91(1):2868 (1985, January)

The relationship between cyclic refrigerant migration and cyclic loss for a residential, split-system air conditioner has been investigated. The cyclic refrigerant migration was measured at different points in the operating cycle by simultaneously shutting five pneumatically operated valves that isolated the refrigerant in the major system components. The refrigerant was then removed, weighed, and returned to the system. The unit tested was found to have a high initial capacity as migrated refrigerant was removed from the evaporator and then a low, slowly increasing capacity as trapped refrigerant was returned to the system from the accumulator. The unit performance was also compared to single and double time constant regressive approximations and to the time constant calculated from the evaporator mass and heat transfer coefficient. Although relationships between migrated refrigerant and cyclic capacity were observed, no practical refrigerant migration test method that would be less burdensome than the cyclic tests of ASHRAE Standard 116 appears possible at this time.

374
Merriman, R.L., Arthur D. Little, Inc., San Francisco, CA

Evaluation of Nonazeotropic Refrigerant Mixtures for Capacity Modulation

CONF-8804100; Research and Development on the Heat Pump for Space Conditioning Applications, Proceedings of the Second DOE/ORNL Heat Pump Conference, Washington, DC, April 17-20, 1988, 225 pp.; (12 pp.) (1988)

The objective of this study is to identify candidate nonazeotropic mixtures and advanced heat pump cycle concepts with emphasis on their potential for single-speed capacity modulation with mixture composition control and to assess the effect of conjunction with non-azeotropic mixture circles evaluate the cycles analytically and recommend the most promising cycles and mixtures for further development.

375
Metz, P.D., M.A. Catan, M. Piraino, R.W. Timmerman, and J. Gleason, Brookhaven National Laboratory, Upton, NY

District Heating and Cooling Technology Selection and Characterization - Final Report

BNL-52001; 175 pp. (1986, March)

This report describes the district heating and cooling (DHC) technology selection and characterization tasks performed under Part I of the project "District Heating and Cooling Market Potential and Penetration Study" for the U.S. Department of Energy. The purpose of this project is to determine the applicability of various DHC technologies to different community types and regions of the country. The results will be used by DOE to guide R and D program planning.

376
Metz, P.D., M.A. Catan, M. Piraino, R.W. Timmerman, and J. Gleason, Brookhaven National Laboratory, Upton, NY

Project Synopsis: District Heating and Cooling Technology Selection and Characterization

CONF-8606188; Proceedings of the 77th Annual International District Heating and Cooling Association Conference, Asheville, NC, June 8, 1986. International District Heating and Cooling Association, Washington, DC; (pp. 405-414) (1986)

This report is a brief synopsis of the district heating and cooling (DHC) technology selection and characterization work performed by Brookhaven National Laboratory for the U.S. Department of Energy. Detailed results are presented in another report. The purpose of this project is to quantify the potential of conventional and innovative district heating and cooling (DHC) space conditioning systems in the U.S. More Specifically, its goal is to determine the applicability of alternative DHC system types to different regions of the country and to identify improvements that enhance system potential.

377
Metz, P.D., and J. Gleason, Brookhaven National Laboratory, Upton, NY

District Heating and Cooling Market Potential and Penetration Methodology - Final Report

BNL-51999; 52 pp. (1986, March)

This report describes the district heating and cooling (DHC) market potential and penetration methodology development tasks performed under Part 1 of the project "District Heating and Cooling Market Potential and Penetration Study" for the U.S. DOE. Market potential and penetration methodologies were surveyed to identify those suitable for assessing the feasibility of DHC systems in the U.S., i.e., of translating the characteristics of each system to its market response. Each methodology was evaluated in terms of its level of detail, data requirements, costs, and other factors. A preferred methodology was developed, and a prognosis for implementing the preferred methodology was made.

378
Meyers, S., Lawrence Berkeley Laboratory, Berkeley, CA

Energy Consumption and Structure of the U.S. Residential Sector: Changes Between 1970 and 1984

LBL-21190; 111 pp. (1986, March)

This report presents a quantitative description of the trends in U.S. residential energy consumption in the 1970 to 1984 period and the chief structural and behavioral changes shaping those trends. We look both at the sector as a whole and at the particular markets for natural gas, electricity, oil, and other fuels. Although the focus is presentation of data, there is also some interpretation and analysis.

379
Miller, W.A., Oak Ridge National Laboratory, Oak Ridge, TN

Laboratory Analysis of On/Off Cycling for an Air-to-Air Heat Pump Operating in the Heating Mode

(1985)

380
Miller, W.A., Oak Ridge National Laboratory, Oak Ridge, TN

Laboratory Experiments of Heat Pump Dynamic Losses

CONF-841231; Research and Development on Heat Pumps for Space Conditioning Applications, Proceedings of the DOE/ORNL Heat Pump Conference, Washington, DC, December 10, 1984; (pp. 45-54) (1985, August)

Air-source heat pump experiments at ORNL (1) provide detailed system and component performance data usable in understanding dynamic loss phenomena and (2) enable formulation and evaluation of methods that could reduce dynamic losses. Results are presented from a series of laboratory experiments performed at ORNL aimed at providing detailed characterization of frosting losses, cycling losses, and defrosting losses as well as steady-state performance data. Continuous modulation heat pump experiments to observe dynamic loss trends under part-load heat pump operation are discussed.

381
Mills, E., R.L. Ritschard, and C.A. Goldman, Lawrence Berkeley Laboratory, Berkeley, CA

Financial Impacts of Energy Conservation Investment in Public Housing

LBL-21741; 19 pp.; CONF-860818; Energy Efficiency in Buildings, Proceedings of the American Council for an Energy Efficient Economy Santa Cruz Summer Study, Santa Cruz, CA, August 17, 1986 (1986, July)

In this study, the relative financial impact on Department of Housing and Urban Development (HUD) and Public Housing Authorities (PHAs) of these four funding strategies, based on case studies of actual retrofit efforts by two local housing authorities: San Francisco, California and Trenton, New Jersey are examined. The selected retrofits all show significant energy savings. This is not, however, reflected in the financial benefits to each party because current provisions of the Performance Funding System (PFS) for public housing energy subsidies require that costs and savings associated with energy conservation retrofits be shared between HUD and the local housing authorities, regardless of the financing mechanism used.

382
Mixon, W.R., Oak Ridge National Laboratory, Oak Ridge, TN

An Overview of the Building Energy Retrofit Research Program

CONF-870911; Improving Building Energy Efficiency in Hot and Humid Climates, Proceedings of the Fourth Annual Symposium, Houston, TX, September 5, 1987; (6 pp.) (1987)

Objectives, approaches, and accomplishments of the Building Energy Retrofit Research Program are discussed. The program sponsored by the Department of Energy focuses on technical, financial, and behavioral barriers to improving energy efficiency of existing buildings through retrofit. The program, organized by the three building sectors, single- family, multi- family, and commercial is implemented with expertise from four national laboratories, Princeton University and the Alliance to Save Energy in cooperation with state, utility and local agencies.

383
Mixon, W.R., and R.J. Kedl, Oak Ridge National Laboratory, Oak Ridge, TN

Predicted Energy Conservation in Existing Small Commercial Buildings

CONF-850606; Proceedings of the Semiannual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Honolulu, HI, June 23-26, 1985; ASHRAE Transactions 91(2B):1510-1515 (1985)

Research has recently been completed to characterize typical small commercial buildings existing in the United States and to assess the potential of retrofit measures to reduce the energy use and peak electric demand. The focus has been on commercial buildings that will be eligible under the Commercial and Apartment Conservation Service (CACS) Program mandated by Congress, i.e., with annual energy consumption less than 48 thousand kW/hr of electricity and 12 thousand therms of any other fuel. Estimates of retrofit energy savings were based on representative physical and energy-use characteristics selected from information collected on 291 small commercial buildings in nine cities. Energy-use profiles varied significantly with building type and location, but total annual energy savings of 26 to 49% were predicted from use of five common retrofit measures in modern strip-type and older two-story building models.

Peak electric demand ranged from 15 to 50 kW for these models, with predicted retrofit savings of 4 to 29 kW.

384
Modahl, R.J., and F.C. Hayes, Trane Company, La Crosse, WI

Evaluation of a Commercial Advanced Absorption Heat Pump Breadboard

CONF-8804100; Research and Development on the Heat Pump for Space Conditioning Applications, Proceedings of the Second DOE/ORNL Heat Pump Conference, Washington, DC, April 17-20, 1988, 225 pp.; (10 pp.) (1988)

An advanced absorption heat pump program is being conducted by the Trane Company, with support from DOE. Evaluation, development, and proof testing of advanced absorption refrigeration cycles which are applicable to residential and commercial heat pumps for space conditioning is the objectives of the program. This paper summarizes results of the development and testing of critical components and breadboard version of the selected system.

385
Modera, M.P., Lawrence Berkeley Laboratory, Berkeley, CA

Technical Description: The Envelope Thermal Test Unit

LBL-17173; 28 pp.; CONF-850105; Field Measurements of Heat Transfer in Building Envelopes, Proceedings of an American Society of Heating, Refrigerating and Air-Conditioning Engineers Symposium, Chicago, IL, January 27, 1985; ASHRAE Transactions 91(1) (1984, January)

Although much information is available on the steady-state thermal performance of walls in a laboratory environment, there is little information concerning either the steady-state or dynamic performance of walls in situ. This report describes a measurement apparatus, the Envelope Thermal Test Unit (ETTU), developed to measure the in situ thermal performance of walls. It includes a description of ETTU's operation, its construction, and the results of tests in the laboratory and in the field. The apparatus is described in detail, including technical specifications of the hardware. The ETTU measurements are compared with predictions made by computer simulation of the heat transfer through the test walls. These comparisons, based upon application of the Simplified Thermal Parameter theory to the interpretation of ETTU measurements, show good agreement with the computer simulations for all of the walls tested, except for the thick concrete wall. It was found that the measurements on the concrete wall were affected by large lateral heat flows.

386
Modera, M.P., Lawrence Berkeley Laboratory, Berkeley, CA

Monitoring the Heat Output of a Wood Stove with Surface Temperature Probes

LBL-17771 (1986, February)

387
Modera, M.P., Lawrence Berkeley Laboratory, Berkeley, CA

Residential Air Leakage Database Compilation: Final Report

LBL-23740; 19 pp. (1986, October)

Under contract to the Department of the Army, the Energy Performance of Buildings Group at Lawrence Berkeley Laboratory compiled a database of residential air leakage measurements. The primary objective of this contract was to compile a readily available sample of the air leakage contract and to assess building characteristics and climate data associated with each measurement. This paper reviews the database.

388
Modera, M.P., Lawrence Berkeley Laboratory, Berkeley, CA

Characterizing the Dynamic Thermal Performance of a Wall Using Periodic Excitation

LBL-24113 (1987)

389
Modera, M.P., R.C. Diamond, and J.T. Brunsell, Lawrence Berkeley Laboratory, Berkeley, CA

Improving Diagnostics and Energy Analysis for Multifamily Buildings: A Case Study

LBL-20247; 30 pp.; CONF-851202; Thermal Performance of the Exterior Envelopes of Buildings - III, Proceedings of the DOE-ORNL-ASHRAE-BTECC Conference, Clearwater Beach, FL, December 2, 1985, 1421 pp. (1986, April)

Multifamily buildings are approximately one quarter of the U.S. housing stock, consuming over two quads of energy per year, and represent a considerable potential for energy conservation. This report describes a case study in multifamily retrofit research performed by Lawrence Berkeley Laboratory (LBL) in collaboration with the city energy office in Minneapolis, MN. The basis for the case study is a one-week experiment in a seven-unit brick apartment building in Minneapolis. The experiment was to use diagnostics that are not conventionally performed in multifamily buildings to evaluate some existing and potential retrofits. The project included a detailed energy balance on the building's brick-set steam boiler and an examination of the air leakage paths throughout the building.

390
Modera, M.P., and F. Peterson, Lawrence Berkeley Laboratory, Berkeley, CA

Reducing Emissions from Wood Stoves by Reducing Wood Surface Area

LBL-22910; CONF-880128; Proceedings of the 1988 American Society of Heating, Refrigerating and Air-Conditioning Engineers Winter Meeting, Dallas, TX, January 30, 1988. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA; ASHRAE Transactions 94(1):1154-1170 (1988)

As a consequence of outdoor air pollution problems being attributed to residential wood burning, wood burning is being restricted in some regions in the U.S., the U.S. Environmental Protection Agency is developing an emission standard for residential wood stoves, and researchers and manufacturers are devoting significant resources to reducing wood-stove emissions. This paper examines experimental results obtained at the Royal Institute of Technology in Sweden showing the carbon monoxide (CO), unburned hydrocarbon (CH sub x), and soot emissions from a wood-burning boiler all decreased when the size of the wood pieces being burned was increased. The physical mechanisms underlying this phenomenon are discussed, and a simple model for predicting pollutant emissions as a function of the size of the individual wood pieces being burned is derived and tested. The model is based upon the oxygen-starved nature of residential wood burning, using the concept of excess wood surface are (surface area in excess of a critical wood surface area) as a surrogate for excess fuel generation. It is found that CO, CH sub x, and soot emissions can all be related to excess surface area by a power-law relationship, and that the relationship is close to linear for both CO and CH sub x emissions. The practical importance of these findings to environmental policies for wood burning is noted.

391
Modera, M.P., and M.H. Sherman, Lawrence Berkeley Laboratory, Berkeley, CA

AC Pressurization: A Technique for Measuring Leakage Area in Residential Buildings

LBL-18395; 25 pp.; CONF-850606; Proceedings of the Semiannual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Honolulu, HI, June 23-26, 1985; ASHRAE Transactions 91(2) (1986, March)

A new technique for measuring the leakage area of residential buildings is presented. This technique, called AC pressurization, is designed to overcome most of the shortcomings of fan pressurization, the conventional technique for measuring leakage area. The fan pressurization technique (often performed using a blower door) has several known deficiencies: (1) the pressures it exerts on the building envelope are significantly higher than those experienced under natural conditions, thereby requiring extrapolation outside of the measurement range to calculate the leakage area; (2) it cannot make real-time leakage area measurements; and (3) the large volumes of air displaced by the fan can cause inconveniences such as large indoor temperature changes.

392
Modera, M.P., and D.J. Wilson, Lawrence Berkeley Laboratory, Berkeley, CA

The Effects of Wind on Residential Building Leakage Measurements

LBL-24195; Air Change Rate and Air Tightness in Buildings, Proceedings of an ASTM Symposium, Atlanta, GA, April 17-18, 1989

393
Mohler, B.L., R.M. Scheer, and V. Barnes, Pacific Northwest Laboratory, Richland, WA

Consumer Decision and Behavior Research Agenda for the Office of Building and Community Systems

PNL-5702; 70 pp. (1985, December)

This report presents a research agenda of Consumer Decision and Behavior Projects related to improving, facilitating and planning Building and Community Systems, (BCS) research and development activities. Information for developing this agenda was gathered through focus group and depth interviews with BCS staff, directors and program managers.

394
Morgan, S.J., Technical Development Corporation, Boston, MA

Weatherizing Homes in Portland: An Evaluation of a Community-Based Residential Conservation Pilot Program

ORNL/Sub-85/06613/1; 42 pp. (1988, February)

Twelve public and private organizations serving Portland, Maine collaborated to establish a comprehensive, one-stop residential conservation program model during the fall and winter of 1984-85. The Weatherization Portland Planning Task Force launched a demonstration program to test the model in two neighborhoods in February and May 1985 and in September. DOE funded an evaluation of the planning process and the demonstration program. The evaluation teams goals were: (1) to promote the use of and improvement of the RCS audit; (2) to provide hands-on training in the installation of low cost and infiltration measures; (3) to stimulate additional purchase of low cost and infiltration measures; (4) to generate loans for energy improvements; and (5) to coalesce existing program providers in the offering of a more comprehensive and coordinated package of services.

395
Mowris, R.J., Lawrence Berkeley Laboratory, Berkeley, CA

Analytical and Numerical Models for Estimating the Effect of Exhaust Ventilation on Radon Entry in Houses with Basements or Crawl Spaces

LBL-22067; 134 pp. (1986, August)

Efforts have been made recently to characterize and map the United States in order to locate areas where content in the soil and high soil permeability might suggest potential problems of higher-than-average indoor radon concentrations in houses (Na858). These data can be used as inputs to a simplified model of radon entry to quickly estimate whether houses in certain locations might have radon problems. This paper is concerned with the development of two such models: (1) a simplified model to predict soil gas flow, and hence radon entry into houses with basements, and (2) a simplified model to predict radon entry into houses with crawl spaces.

396
Mowris, R.J., and W.J. Fisk, Lawrence Berkeley Laboratory, Berkeley, CA

Modeling the Effects of Exhaust Ventilation on Radon Entry Rates and Indoor Radon Concentrations

LBL-22939; Health Physics 54:491 (1987)

397
Mullei, W.A., Oak Ridge National Laboratory, Oak Ridge, TN

Laboratory Capacity Modulation Experiments, Analyses and Validation

CONF-8804100; Research and Development on the Heat Pump for Space Conditioning Applications, Proceedings of the Second DOE/ORNL Heat Pump Conference, Washington, DC, April 17-20, 1988, 225 pp.; (15 pp.) (1988)

A combined experimental and analytical project was conducted on a breadboarded continuously-variable speed air-to-air heat pump (CVSHP). The split-system residential unit of nominal 2-3/4-ton (9, 7-kW) cooling capacity was instrumented and tested in environmental chambers. The steady-state, frosting/demand defrosting, and cycling efficiency characteristics of the CVSHP with first generation components (e.g., heat exchangers, compressor, and indoor blower, both having variable speed induction motors) were measured in the laboratory for compressor drive frequencies ranging from 15 through 90 Hz. Steady-state efficiency data were used to validate an initial version of the Oak Ridge National Laboratory steady-state modulating heat pump design program.

398
Mulroy, W.J., National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

The Effect of Short Cycling and Fan Delay on the Efficiency of a Modified Residential Heat Pump

CONF-860106; Proceedings of the Semiannual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, San Francisco, CA, January 19, 1986; ASHRAE Transactions 92(1B):813-826 (1986)

The object of this study was to determine if the use of a cycling controller would improve the efficiency of a residential air conditioner or heat pump. Cyclic tests were performed on a capillary tube heat pump in three configurations: as manufactured, as modified to simulate a non-bleed expansion valve unit by operation of a valve in the liquid line, and as modified to simulate an air conditioner by elimination of the accumulator. The two modifications, the liquid valve installation and accumulator removal, were found to greatly improve the cyclic performance to about equal levels; however, some cyclic losses remained. It was concluded that any control strategy that resulted in shortened on-cycle run times would reduce cyclic efficiency for all designs tested. It was further concluded, based in part on the work of others, that fan delay is an undesirable control strategy for units that have the indoor air handler and coil installed within the conditioned space.

399
Mulroy, W.J., and D.A. Didion, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

The Performance of a Conventional Residential-Sized Heat Pump Operating with a Nonazeotropic Binary Refrigerant Mixture

NBSIR-86-3422; PB-87-152286/XAB; 67 pp. (1986, October)

The report presents laboratory-performance measurements of a relatively unmodified residential heat pump designed for R22 when charged with a nonazeotropic, binary mixture of R13B1 and R152a. Results are presented for various sizes of fixed-expansion devices. The effect of gliding temperature within the saturation zone was found to be small. The experimental investigation confirmed that flash distillation within the accumulator would improve low-temperature heating performance. The measured performance was approximately 11% lower in both efficiency and capacity than R22 for air conditioning. The high-temperature heating efficiency was 3% lower than R22. The low-temperature heating capacity was 14% higher and efficiency 2% higher than R22. These results show a substantial improvement over R22 for heating applications at the expense of reduced cooling-mode performance. Further performance enhancement for this or other mixtures is expected through various system modifications that remain to be studied.

400

Mulroy, W.J., M. Kauffeld, M.O. McLinden, and D.A. Didion, Oak Ridge National Laboratory, Oak Ridge, TN

Experimental Evaluation of Two Refrigerant Mixtures in a Breadboard Air Conditioner

CONF-8804100; Research and Development on the Heat Pump for Space Conditioning Applications, Proceedings of the Second DOE/ORNL Heat Pump Conference, Washington, DC, April 17-20, 1988, 225 pp.; (7 pp.) (1988)

An experimental water-to-water breadboard heat pump was constructed for comparison of pure R22/R114 and R13/R12. Three evaporator configurations were studied and in all cases the best mixture outperformed R22. Other observations were that mixtures can take advantage of heat exchangers efficiency and that heat exchange between the condensed and evaporating refrigerant is beneficial to some mixed refrigerants. Researchers also conclude that mixtures exhibit nonlinearity of enthalpy versus temperature in two phases region, which have significant impact on both heat exchanger and cycle design.

401

Murphy, K.P., et al., Oak Ridge National Laboratory, Oak Ridge, TN

Development of a Residential Gas-Fired Absorption Heat Pump: Physical and Thermodynamic Properties of R123a/ETFE - System Development and Testing and Economic Analysis

ORNL/Sub-79/24610/4 (1985, August)

This is the fifth in a series of reports covering work on the development of a residential-sized absorption heat pump using organic type working fluids. This report covers the development work on the R123a/Ethyltetrahydrofurfurylether (ETFE) pair and an economic analysis of the system. Extensive thermodynamic and physical properties of the R123a/ETFE system were developed. Theoretical analysis of the data was made and showed very good performance. Subsequent testings on equipment not fully developed for R123a/ETFE confirmed this very good performance. The economic analysis showed the system competitive in most areas of the U.S. if improved performance goals (COP=1.5) can be met. The most important factors in determining the competitiveness are heating to cooling ratios and the relative cost of gas and electric.

402

Murphy, R.W., Oak Ridge National Laboratory, Oak Ridge, TN

An Analytical Study of Hybrid Ejector/Internal Combustion Engine-Driven Heat Pumps

CONF-8804100; Research and Development on the Heat Pump for Space Conditioning Applications, Proceedings of the Second DOE/ORNL Heat Pump Conference, Washington, DC, April 17-20, 1988, 225 pp.; (8 pp.) (1988)

Because ejectors can combine high reliability with low maintenance cost in a package requiring little capital investment, they may provide attractive heat pumping capabilities according to researchers. A hybrid system in which an ejector driven by engine reject heat is analyzed by modifying an ejector heat pump and combining it with generic compressor and internal combustion engine models. Results of the study are presented.

403
National Bureau of Standards, Washington, DC

Algorithms for Calculating Radiation View Factors Between Plane Convex Polygons with Obstructions

HTD-Vol-72; Fundamentals and Applications of Radiation Heat Transfer; (45 pp.) (1986)

Methods for calculating view factors between plane polygons are described and compared. Gaussian integration significantly improves the performance of line integral methods. A shadow projection method combined with line integral evaluation is shown to be more accurate and possibly faster than conventional methods for evaluating view factors with obstructing surfaces. This report will examine algorithms for computing view factors using improved line integral and computer graphics methods with special emphasis on the processing of view obstructions. It is based on an NBS report, NBSIR-86-3463, where more details are available.

404
Navvab, M., M. Karayel, and E. Ne'eman, Lawrence Berkeley Laboratory, Berkeley, CA

Analysis of Luminous Efficacy for Daylighting Calculations

LBL-22616; CONF-861109; Architecture and Natural Light, Proceedings of the Second International Daylighting Conference, Long Beach, CA, November 5-7, 1986 (1986, November)

405
Navvab, M., M. Karayel, E. Ne'eman, and S. Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

Daylight Availability Data for San Francisco

Energy and Buildings 6(3):273 (1984)

Horizontal and vertical surface measurements were taken by nine sensors at 15-minute intervals under all sky and sun conditions. Equations are derived for clear sky global, direct, and diffuse illuminance and irradiance on a horizontal surface as a function of solar altitude, and for overcast sky horizontal illuminance and irradiance.

406
Navvab, M., M. Karayel, E. Ne'eman, and S. Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

Analysis of Atmospheric Turbidity for Daylight Calculations

Energy and Buildings 6(3):293 (1984)

Predicting the illuminance from direct sun or sky on clear days is essential to any study of daylighting strategies. This article presents a set of illuminance and irradiance data collected for four years at 15-minute intervals in San Francisco. This data has been used to investigate the impact of atmospheric turbidity on daylight calculations.

407
Nazaroff, W.W., Lawrence Berkeley Laboratory, Berkeley, CA

Reply to T.W. D'Ottavio and R.N. Dieta: Discussion of Radon Transport into a Detached One-Story House with a Basement

LBL-20095; Atmospheric Environment 20(5):1067 (1986)

Eleven portable air cleaning devices have been evaluated for control of indoor concentrations of respirable particles, and their concomitant effects on radon progeny concentrations have been investigated. The experiments were conducted in a room-size chamber using cigarette smoke and radon injection from an external source. Of the devices examined the electrostatic precipitators and extended surface filters had significant particle removal rates, while the particle removal rates for several small panel-filters, an ion-generator, and a pair of mixing fans were found to be essentially negligible. The evaluation of radon progeny control produced similar results; the air cleaners which were effective in removing particles were also effective in reducing radon progeny concentrations. At the low particle concentrations, deposition of the unattached radon progeny on room surfaces was found to be a significant removal mechanism. Deposition rates of attached and unattached progeny have been estimated from these data, and were used to calculate the equilibrium factors for total and unattached progeny concentrations as a function of particle concentration. While particle removal reduces total airborne radon progeny concentrations, the relative alpha decay dose to the lungs appears to change very little as the particle concentration decreases due to the greater radiological importance of unattached progeny.

408

Nazaroff, W.W., Lawrence Berkeley Laboratory, Berkeley, CA

Predicting the Rate of Radon-222 Entry from Soil into the Basement of a Dwelling Due to Pressure-Driver Air Flow

LBL-25762 (1987, November)

Indoor air quality surveys conducted in the Spokane River Valley/Rathdrum Prairie Region of eastern Washington and northern Idaho identified a significant number of houses with indoor radon concentrations above the Bonneville Power Administration (BPA) and Environmental Protection Agency (EPA) guidelines. A detailed study was conducted to develop and evaluate radon mitigation techniques and strategies. Fourteen houses in the Spokane, Washington region and one house in Vancouver, Washington were selected to participate in the study. The fourteen homes were typical of the housing stock in the region and spanned a wide range of age, size, substructure type and energy conserving construction. Two of the homes served as controls during the term of the study and were subsequently mitigated at the termination of the project. The primary objectives of the study were to: (1) examine the efficacy of selected, previously utilized radon control techniques in various configurations; (2) develop, test, and evaluate innovative radon control techniques and strategies; (3) gain additional understanding of radon entry mechanisms and the subsequent effect of control techniques, and combination of techniques, on these mechanisms; (4) collect data on detailed installation and operation costs for the various control techniques; and (5) achieve effective, long-term reduction of indoor radon concentrations in each of the study houses such that the average heating season concentrations are below 5 pCi/l.

409

Nazaroff, W.W., and S.M. Doyle, Lawrence Berkeley Laboratory, Berkeley, CA

Radon Entry into Houses Having Crawl Space

LBL-16637; Health Physics 48(3):265-281 (1985, March)

The transport of Rn-222 from soil, through a vented crawl space, and into the living space of single-family residences was studied. Two houses were monitored in detail for periods of 5 and 7 weeks. The data suggest that, of the Rn released into the crawl space from the soil beneath the house, a significant fraction, perhaps 50% or more, enters the living space. The effect of 3 meteorological parameters - wind speed, indoor-outdoor temperature difference, and rate of barometric pressure change - on Rn concentration and entry rate were examined. In 1 of the houses a higher temperature difference corresponded to a higher indoor concentration, suggesting that the increased infiltration rate is more than compensated by an increase in the Rn entry rate. On the other hand, a high wind speed tended to reduce the indoor concentration, presumably by increasing both cross-ventilation of the crawl space and the infiltration rate of the living space. Results suggest that Rn transport into the crawl space of at least 1 of the houses occurred by pressure-driven flow, rather than solely by molecular diffusion. A third house was studied using a tracer gas injected into the crawl space at a controlled rate. The fraction of air leaving the crawl space that entered the living space ranged from 0.3 to 0.65. By sealing leaks in the floor of this house, the average infiltration rate was reduced by 25%, but the indoor concentration of the tracer gas remained constant.

410
Nazaroff, W.W., et al., Lawrence Berkeley Laboratory, Berkeley, CA

Factors Influencing Soil as a Source of Indoor Radon: A Framework for Geographically Assessing Radon Source Potentials

LBL-20645 (Rev.) (1988, July)

411
Nazaroff, W.W., et al.

Radon Entry via Potable Water

Radon and Its Decay Products in Indoor Air, W.W. Nazaroff and A.V. Nero (eds.). John Wiley Publishers, New York, NY; (pp. 131-157) (1988)

412
Nazaroff, W.W., H.E. Feustel, A.V. Nero, K.L. Revzan, D.T. Grimsrud, M.A. Essling, and R.E. Toohey, Lawrence Berkeley Laboratory, Berkeley, CA; Argonne National Laboratory, Argonne, IL

Radon Transport into a Detached One-Story House With a Basement

LBL-16572; Atmospheric Environment 19(1):31-46 (1985)

The results are presented for a five-month study during which Rn-222 (radon) concentration, air-exchange (or ventilation) rate, and weather and radon source parameters were continuously monitored in a house near Chicago, with a view to accounting for the radon entry rate. The results suggest that the basement sump and perimeter drain-tile system played an important role in influencing the radon entry rate and that pressure-driven flow was more important than diffusion as a mechanism for radon entry.

413
Nazaroff, W.W., B.A. Moed, and R.G. Sextro

Soil as a Source of Indoor Radon: Generation, Migration and Entry

Radon and Its Decay Products in Indoor Air, W.W. Nazaroff and A.V. Nero (eds.). John Wiley Publishers, New York, NY; (pp. 57-112) (1988)

414
Nelson, B.D., D.A. Robinson, G.D. Nelson, and M. Hutchinson, Oak Ridge National Laboratory, Oak Ridge, TN

Energy Efficient House Research Project

ORNL/Sub-83/47980/1 (1986)

This document is the final report for the Energy Efficient House Research Project. The basis for this project was a set of energy efficient houses built in 1980 by the Energy Efficient Housing Demonstration Program of the Minnesota Housing Finance Agency. Under this program, 144 detached and attached housing units were constructed throughout the State of Minnesota by 23 different builders. The research project utilized a simple data collection method involving homeowners in the field and utility data reports to establish a performance data base for the houses in the study. Data have been provided for addition to the BECA-A (new residential) data base on file at Lawrence Berkeley Laboratory, establishing a comprehensive data base for further analyses. The 112 houses for which there were good quality energy data performed very well, but analysis of these data showed few significant correlations between energy performance and design features. The effectiveness of increased solar aperture or the use of night window insulation in reducing space heat energy consumption could not be proved or disproved statistically. One result, however, that did prove to be consistently significant was the loss of space heating energy due to the presence of below slab forced air distribution systems.

415
Nephew, E.A., and J.C. Moyers, Oak Ridge

National Laboratory, Oak Ridge, TN

Scoping Evaluation of Potential Benefits of Zoning with Residential Space-Conditioning Systems

CONF-841231; Research and Development on Heat Pumps for Space Conditioning Applications, Proceedings of the DOE/ORNL Heat Pump Conference, Washington, DC, December 10, 1984; (pp. 69-73) (1985, August)

The potential for load reduction through zoning and for the reduction of national energy use deriving from application of variable-capacity heat pumps in zoned residential space conditioning was evaluated. Load reductions of 30-50% of full-time, whole-house loads were estimated to be attainable through combined zoning and temporal temperature setback that created no loss of comfort in the occupied zones. Load reductions of up to 60% were attainable when a portion of the house was unoccupied and received only minimal space conditioning. Maximum potential national energy savings, achievable through complete market penetration, of 1.7 and 2.1 quads/year were estimated for the fully occupied and partially occupied residences.

416

Nero, A.V., Lawrence Berkeley Laboratory, Berkeley, CA

Indoor Concentrations of Radon-222 and Its Daughters: Sources, Range, and Environmental Influences

LBL-19346; 27 pp.; CONF-8410136; Indoor-Air and Human Health: Major Indoor Air Pollutant and Their Health Implications, Proceedings of the Seventh ORNL Life Sciences Symposium, Knoxville, TN, October 29, 1985 (1985, April)

A review of factors affecting indoor concentrations of radon-222 and its daughters is presented. In U.S. single-family homes, radon concentrations are found to average about 1.5 pCi/l, but substantially higher concentrations occur frequently: perhaps a million U.S. homes have concentrations exceeding 8 pCi/l (from which occupants receive radiation doses comparable to those now experienced by uranium miners). The major contributor to indoor radon is ordinary soil underlying homes, with this radon being transported indoors primarily by the slight depressurization that occurs toward the bottom of a house interior (due to indoor-outdoor temperature differences and winds). Water from underground sources contributes significantly in a minority of cases, primarily residences with private wells, with public water supplies contributing only a few percent of indoor radon, even when drawn from wells. The strong variability in indoor concentrations is associated primarily with variability in the amount of radon entering homes from these various sources, and secondarily with differences in ventilation rates.

417

Nero, A.V., Lawrence Berkeley Laboratory, Berkeley, CA

Distribution of Indoor Radon Concentrations and Elements of a Strategy for Control

LBL-21641; 19 pp.; CONF-8603172; Indoor Radon, Proceedings of the Governor's Conference, Albany, NY, March 4-5, 1986; (p. 38) (1986, May)

Indoor radon concentrations vary widely in the U.S. housing stock, with normal concentrations estimated to cause a significant risk of lung cancer by comparison with environmental exposures normally considered, and high concentrations causing risks that exceed even those from cigarette smoking. The probability distribution, i.e., the number of houses at various concentrations, can be estimated from an analysis of the U.S. indoor radon data accumulated to date. Such an analysis suggests that in about a million houses, occupants are receiving exposures greater than those experienced by uranium miners. The form of the frequency distribution, including not only the average concentration, but also the number of houses with high levels, has substantial influence on strategies for control of indoor radon. Such strategies require three major elements: formulation of control objectives in terms of guidelines for remedial action and for new houses; selection of means for identifying homes with high concentrations; and a framework for deciding what types of control measures are appropriate to particular circumstances and how rapidly they should be employed.

418
Nero, A.V., Lawrence Berkeley Laboratory, Berkeley, CA

Estimated Risk for Exposure to Radon Decay Products in U.S. Homes

LBL-21642; 19 pp.; CONF-8509332; Exposure Modeling and Monitoring, Proceedings of a Workshop, Cambridge, MA, September 30, 1985 (1986, May)

Recent analyses now permit direct estimation of the risks of lung cancer from radon decay products in U.S. homes. Analysis of data from indoor monitoring in single-family homes yields a tentative frequency distribution of annual-average Rn-222 concentrations averaging 55 Bq/cu m and having 2% of homes exceeding 300 Bq/cu m. Application of the results of occupational epidemiological studies, either directly or using recent advances in lung dosimetry, to indoor exposures suggests that the average indoor concentration entails a lifetime risk of lung cancer of 0.3% or about 10% of the total risk of lung cancer. The risk to individuals occupying the homes with 300 Bq/cu m or more for their lifetimes is estimated to exceed 2%, with risks from the homes with thousands of Bq/cu m correspondingly higher, even exceeding the total risk of premature death due to cigarette smoking. The potential for such average and high-level risks in ordinary homes forces development of a new perspective on environmental exposures.

419
Nero, A.V., Lawrence Berkeley Laboratory, Berkeley, CA

Elements of a Strategy for Control of Indoor Radon

LBL-22507; Radon and Its Decay Products in Indoor Air, W.W. Nazaroff and A.V. Nero (eds.). John Wiley Publishers, New York, NY; (pp. 459-487) (1988)

420
Nero, A.V., Lawrence Berkeley Laboratory, Berkeley, CA

Radon and Its Decay Products in Indoor Air - An Overview

LBL-22644; Radon and Its Decay Products in Indoor Air, W.W. Nazaroff and A.V. Nero (eds.). John Wiley Publishers, New York, NY; (pp. 1-53) (1988)

421
Nero, A.V., Institute for Water, Soil and Air Hygiene, Berlin, Federal Republic of Germany

Elements of Strategies for Control of Indoor Air Quality

LBL-23139; CONF-870853; Indoor Air '87: Indoor Air Quality and Climate - Volume 3, B. Seifert, B., H. Esdorn, M. Fischer, H. Rueden, and J. Wegner, (eds.), Proceedings of the Fourth International Conference, Berlin, Federal Republic of Germany, August 17-21, 1987 (1987)

422
Nero, A.V., K.L. Revzan, and R.G. Sextro, Lawrence Berkeley Laboratory, Berkeley, CA

Appraisal of the U.S. Data on Indoor Radon Concentrations

LBL-24345; 11 pp.; CONF-871208; The Natural Radiation Environment, Proceedings of the Fourth International Symposium, Lisbon, Portugal, December 7, 1987 (1987, November)

Monitoring efforts undertaken before 1985 indicate that the radon concentration in U.S. houses averages approximately 55 Bq/cu m and that, in approximately 6%, annual-average levels exceed 150 Bq/cu m, with perhaps 1-2% having 300 Bq/cu m or more. However, several recent large-scale data sets yield average concentrations of 100-150 Bq/cu m, with perhaps 20% of results exceeding 150 Bq/cu m, leading many to conclude that the U.S. frequency distribution is substantially higher than previously indicated. In fact, this conclusion is unfounded, and the public, policy makers, and even scientists are being misled by inappropriate use of data. In particular, these recent data sets overrepresent high-concentration houses or include sampling performed in basements or in the winter only. Adequate information is not available to adjust these results precisely to annual-average indoor concentrations experienced by the population, but plausible corrections yield results that are consistent with the distributions previously found.

423

Nero, A.V., M.B. Schwehr, W.W. Nazaroff, and K.L. Revzan, Lawrence Berkeley Laboratory, Berkeley, CA

Distribution of Airborne Radon-222 Concentrations in U.S. Homes

Science 4779:992-997 (1986, November 21)

Apparently large exposures of the general public to the radioactive decay products of radon-222 present in indoor air have led to systematical appraisal of monitoring data from U.S. single-family homes; several ways of aggregating data were used that take into account differences in sample selection and season of measurements. The resulting distribution of annual-average radon-222 concentrations can be characterized by an arithmetic mean of 1.5 pCi/l (55 Bq/cu m) and a long tail with 1 to 3% of homes exceeding 8 pCi/l, or by a geometric mean of 0.9 pCi/l and a geometric standard deviation of about 2.8. The standard deviation in the means is 15%, estimated from the number and variability of the available data sets, but the total uncertainty is larger because these data may not be representative. Available dose-response data suggest that an average of 1.5 pCi/l contributes about 0.3% lifetime risk of lung cancer and that, in the million homes with the highest concentrations, where annual exposures approximate or exceed those received by underground uranium miners, long-term occupants suffer an added lifetime risk of at least 2%, reaching extraordinary values at the highest concentrations observed.

424

Nero, A.V., R.G. Sextro, S.M. Doyle, B.A. Moed, W.W. Nazaroff, K.L. Revzan, and M.B. Schwehr, Lawrence Berkeley Laboratory, Berkeley, CA

Characterizing the Sources, Range, and Environmental Influences of Radon-222 and Its Decay Products

LBL-19869; EEB-Vent-85-9; 16 pp. (1985, June)

Recent results from our group directly assist efforts to identify and control excessive concentrations of radon-222 and its decay products in residential environments. We have demonstrated directly the importance of pressure-induced flow of soil gas for transport of radon from the ground into houses. Analysis of available information from measurements of concentration in U.S. homes has resulted in a quantitative appreciation of the distribution of indoor levels, including the degree of dependence on geographic location. Experiments on the effectiveness of air cleaning devices for removal of particles and radon decay products indicate the potential and limitations of this approach to control.

425

New Jersey Institute of Technology, Newark, NJ

Building Materials Research Agenda

ORNL/Sub-84/97333/1; 132 pp. (1986, April)

An ad hoc panel of individuals was organized to propose a research agenda, scope and objectives that the DOE/ORNL Building Materials Research Program should pursue. The panel recognized accomplishments and advances made over the past five years in selecting agenda projects. The panel composed an extensive list of candidate research projects and selected twenty-four as most significant. Each of the twenty-four projects was characterized by two page descriptions which detailed objectives, scope, problem significance, technical approach, and research products. The panel recommended that DOE/ORNL consider these projects for funding over the next three to five years.

426
Nicol, J.L., and T.K. Stovall, Oak Ridge National Laboratory, Oak Ridge, TN

Cost-Effectiveness of Single and Multiple CACS Retrofit Actions in Multifamily Apartment Buildings

ORNL/CON-191; 57 pp. (1986, March)

This report assesses the cost-effectiveness of energy conservation measures in apartment buildings in varying climatic regions. Five measures: roof insulation, wall insulation, storm windows, caulking and weatherstripping, and night setback/setup of thermostats were considered in great detail; other measures, such as heating and cooling equipment modifications, were considered in a more limited fashion. In general, payback periods for measures tended to increase with decreasing heating degree days and were usually lower for a high-rise building than for a low-rise building. When electric demand charges were considered, the payback periods were slightly shorter. Energy savings for storm windows and caulking and weatherstripping were strongly affected by the assumed infiltration reduction. Caulking and weatherstripping appeared to be cost-effective in most of the climates considered. Wall insulation was only cost-effective when added incrementally to prerequired exterior wall changes. The interaction among multiple measures installed together did not greatly alter the cost-effectiveness of the measures.

427
Oak Ridge National Laboratory, Oak Ridge, TN

Mathematical Modeling of Roof Systems

CONF-8809314; Proceedings of an International Symposium, Oak Ridge, TN, September 15, 1988, 173 pp. (1988)

It has been a long hiatus since the first assemblage of roof modelers in November 1981. The Proceedings of that workshop have stood as the only dedicated testament of the attempts to formalize roofing performance into mathematical precepts and formulas. Now, thanks to a strong effort by a very active organizing committee, we have an update. The invited papers provide good insight into the status of mathematical modeling. It is clear that modelers are becoming more sophisticated in the way they address the major constituents of a roof, the membrane and the insulation. Bonafont's paper on the visco-elastic properties of bitumen, the comprehensive French membrane model with non-linear coefficients, and the versatile heat transfer model of Wilkes are examples. It is also clear that not much is being done yet with whole roof modeling (i.e, interrelationships between components and combined heat, moisture, and structural analysis.)

428
Oak Ridge National Laboratory, Oak Ridge, TN

Single-Family Building Retrofit Research: Multi-Year Plan - FY 1986-FY 1991

ORNL/CON-207; 143 pp. (1986, May)

This Multi-Year Plan describes a research and development (R&D) agenda that will support private sector and public sector efforts to improve the energy efficiency of existing single-family (S-F) buildings. The Plan provides an overview of the characteristics of the S-F sector and summarizes private and government activities that have been directed at energy conservation retrofits in S-F buildings. The S-F Retrofit Research Program focuses primarily on space heating, air conditioning, and domestic hot water. These functions utilize about two-thirds of the residential energy supply. The annual energy use for all residential (S-F and M-F) space conditioning and domestic hot water is 5.5 quads (end use or 9.2 quads (primary). The total potential energy savings for S-F households is 1.4 quads (end use) or 2.2 quads (primary). In terms of 1982 dollars, the potential residential savings would be worth an average of about $8 billion per year if all the potential could be captured. The research and information needs for the S-F Retrofit Research Program were classified into five areas: (1) program planning and support, (2) research on the application of retrofit measures/approaches, (3) basic applied research on new/improved retrofit measures, (4) technology adoption R&D, and (5) technology transfer.

429
Oak Ridge National Laboratory, Oak Ridge, TN

The Roof Research Center: A National User Facility for Thermal Performance and Durability of Roofing Systems - Interim Users Manual

ORNL/M-329; 21 pp. (1987, April 10)

A brief background on the capabilities of the Roof Research Center, along with details on how the facility operates is included in this manual. This interim manual predates the availability of the Large Scale Climate Stimulator (LSCS) - principle facility of the Roof Research Center.

430
Oak Ridge National Laboratory, Oak Ridge, TN

Hermetic Bellows Seal for Braun Linear Engine-Design, Test, and Demonstration

ORNL/Sub-80/61613/1 (1985, June)

Defining seal requirements, analyzing and testing seal performance to develop a design data base, and applying that design criteria to evolve a seal solution suitable for application to a light-commercial-sized heat pump were performed in this project.

431
Oak Ridge National Laboratory, Oak Ridge, TN

Free-Piston Stirling Engine Diaphragm-Coupled Heat-Actuated Heat Pump Component Technology Program: Phase 1/1A Final Report

ORNL/Sub-80/61618/1 (1985, June)

432
Oak Ridge National Laboratory, Oak Ridge, TN

A Comparative Analysis of Utility- and Non-Utility-Based Energy Service Companies: A Case Study Approach

ORNL/Sub-84/19701/1; 91 pp. (1987, January)

Numerous studies over the past decade have documented the potential for household energy savings. Few studies, however, have explored energy service companies, a new residential delivery system that has the potential for increasing residential conservation by assuming responsibility for the major elements of "one stop shopping" - technology choice, auditing, financing, installation, inspection and monitoring. Nor have studies to date analyzed the difference between ESCOs operating in the residential and commercial and industrial (C&I) markets. In order to fill this need, the Consumer Energy Council of America Research Foundation (CECA) has launched a project, with support from Oak Ridge National Laboratory and U.S. Department of Energy, to explore how energy service companies are addressing barriers to widespread conservation in the residential market. Six energy service companies specializing in the residential sector were selected as case studies.

433
Offermann, F.J., R.G. Sextro, W.J. Fisk, D.T. Grimsrud, W.W. Nazaroff, A.V. Nero, K.L. Revzan, and J. Yater, Lawrence Berkeley Laboratory, Berkeley, CA

Control of Respirable Particles in Indoor Air With Portable Air Cleaners

Atmospheric Environment 19(11):1761-1771 (1985)

Eleven portable air cleaning devices have been evaluated for control of indoor concentrations of respirable particles using in situ chamber decay tests. Following injection of cigarette smoke in a room-size chamber, decay rates for particle concentrations were obtained for total number concentration and for number concentration by particle size with and without air cleaner operation. The size distribution of the tobacco smoke particles was log normal with a count median diameter of 0.15 m and a geometric standard deviation of 2.0. Without air cleaner operation, the natural mass-averaged surface deposition rate of particles was observed to be 0.1 h. Air cleaning rates for particles were found to be negligible for several small panel-filter devices, a residential-sized ion-generator, and a pair of mixing fans. Electrostatic precipitators and extended surface filters removed particles at substantial rates, and a HEPA-type filter was most efficient air cleaner studied.

434
Ohlemiller, T.J., National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Forced Smolder Propagation and the Transition to Flaming in Cellulosic Insulation

NBSIR-85-3212 (1985, October)

435
Ohlemiller, T.J., T. Kashiwagi, and K. Werner, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Products of Wood Gasification

NBSIR-85-3127; 115 pp. (1985, April)

The increasing problem of pollution from wood-burning stoves has prompted this examination of the basic gasification process of wood under conditions encompassing those in stoves. Other variables were sample grain orientation, thickness, exposure time, and moisture content. Sample weight was followed in some tests; sample temperature (5 thermocouples) was followed in others. In all tests, all evolved products were either monitored (H_2O, CO, CO_2, total hydrocarbons not condensible at -40 C) or trapped and analyzed (condensible organic species) by gas chromatography and mass spectroscopy. Chromatographic fingerprints of the organic condensate indicated that its composition does not vary a great deal for the conditions examined here. The fingerprints from the radiative heating tests bear a strong resemblance to those of the smoke condensate from a wood stove.

436
Ostrogorsky, A.G., and L.R. Glicksman, Massachusetts Institute of Technology, Cambridge, MA

Aging of Polyurethane Foams - The Influence of Gas Diffusion on Thermal Conductivity

ORNL/Sub-84/9009/2; 111 pp. (1986, August)

It was shown that gas diffusion in closed-cell foams is driven by partial pressure only and not by temperature gradient. The value of the foam effective thermal conductivity can be predicted rapidly and accurately by the developed ECVA code, when the diffusion coefficients of N_2, O_2, CO_2 and fluorocarbon 11 are known. The code can predict the aging rate in different thermal environments. The effective diffusion coefficient can be obtained with sufficient accuracy from the analytical or electrical model, or can be measured directly by the rapid steady state technique. It was found that porous layers exists at the foam/facing interface and inside of the foam panels. By eliminating these layers, the aging performance of the foam can be substantially improved.

437
Pansky, S.H., Pacific Northwest Laboratory, Richland, WA

Holding Down The High Cost of Energy

PNL-SA-12233 (1985, February)

438
Pansky, S.H., Pacific Northwest Laboratory, Richland, WA

How to Save Money With Automatic Daylighting

PNL-SA-12762 (1986, January)

439
Papamichael, K., J.H. Klems, and S. Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

Determination and Application of Bidirectional Solar-Optical Properties of Fenestration Systems

LBL-25124; 9 pp.; CONF-880615; Solar '88, Proceedings of the American Solar Energy Society 1988 Annual Meeting and the 13th National Passive Solar Conference, Cambridge, MA, June 19-24, 1988 (1988, March)

The use of daylight for ambient illumination can substantially reduce this energy usage if the electric lighting system is properly controlled in response to available daylight. This paper evaluates the monitored performance of an integrated lighting system in a recently completed 56,000-sq m office structure in the San Francisco Bay Area. The paper presents a summary of daylighting and electric lighting performance as monitored in several zones of the building. Analysis of detailed measurements on the third floor for four unoccupied days in May indicates that on the brighter south side, the potential for dimming during occupied periods is to 44% of full power. The paper also discusses the potential benefits of daylighting in the context of the overall building electrical energy use. Analysis of annual electricity use indicates that the ambient lighting electrical circuits represent 23% of the total building electricity use.

440
Papamichael, K., and S. Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

The Luminous Performance of Vertical and Horizontal Slate-Type Shading Devices

LBL-21361; CONF-8608179; Proceedings of the 1986 Annual Illuminating Engineering Society Conference, Boston, MA, August 17-21, 1986 (1986)

441
Papamichael, K., and S. Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

Simulating the Luminous and Thermal Performance of Fenestration Systems

LBL-24243; Lighting Design and Application (1987, October):37-45 (1987, October)

442
Papamichael, K., and F.C. Winkelmann, Lawrence Berkeley Laboratory, Berkeley, CA

Solar-Optical Properties of Multilayer Fenestration Systems

LBL-20543; 7 pp.; CONF-861109; Architecture and Natural Light, Proceedings of the Second International Daylighting Conference, Long Beach, CA, November 5-7, 1986 (1986, November)

The bidirectional solar-optical properties of a fenestration system are necessary to accurately determine its luminous and thermal performance. Bidirectional transmittance and reflectance can be determined experimentally for fenestration systems of arbitrary complexity using a scanning radiometer, after which the total directional absorptance can be calculated. However, for the case of multilayer fenestration systems, this approach does not provide information about the net absorptance of each layer. Moreover, the same layers can be ordered in more than one way, resulting in fenestration systems with different solar-optical properties, the determination which requires additional experimental procedures. This paper describes a mathematical model for the calculation of the bidirectional solar-optical properties of multi-layer fenestration systems, using the bidirectional solar-optical properties of each layer. The model is based on the representation of the bidirectional solar-optical properties using matrices. Matrix operations are then used to calculate the bidirectional solar-optical properties of any combination of layers, considering the interreflections between them. This approach offers two advantages: (1) the reduction of the experimental procedures to those required for the determination of the bidirectional transmittance and reflectance of fenestration layers, rather than complete fenestration systems, and (2) the determination of the net absorptance of each layer as part of the fenestration system, rather than the total absorptance of the complete fenestration system.

443
Park, C., National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Demand Lighting Algorithms for Energy Management and Control Systems

NBSIR-84-2826; 89 pp. (1984)

Demand lighting control is one of the popular control strategies for electrical energy management in energy management and control systems in commercial/office buildings. Description of fixed systems in interval metering and window metering for electrical demands are included. Demand limiting calculation procedures discussed are ideal rate, the predictive, and the instantaneous rate methods.

444
Park, J.E., and J.R. Kirkpatrick, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, TN

Heat Loss Through Building Envelopes Due to Convective Loops

K/CSD/TM-80; 71 pp. (1988, October)

The convective motion of air trapped in a building cavity can, under some circumstances, increase the amount of energy lost through the cavity greatly over that expected from a conduction-based analysis. The behavior and economic consequences of such "convective loops" are not well understood. To gain some insight into the thermal behavior of the loops and into the prospects for numerical simulation as a means of evaluating that behavior, computer models for a few such loops have been developed. In this report, those models are described, solutions for two loops are presented, and the prospects for analysis of several other loops are examined.

445
Parken, W.H., et al., National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Field Performance of Three Residential Heat Pumps in the Cooling Mode

NBSIR-85-3107 (1985, March)

446
Pavy, B., and B.G. Rennex, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Circular and Square Edge Effect Study for Guarded-Hot-Place and Heat-Flow-Meter Apparatus

Journal of Thermal Insulation (1986, April)

447
Pearman, N.A., Oak Ridge National Laboratory, Oak Ridge, TN; Honeywell, Inc., Golden Valley, MN

A Combustion System Seasonal Efficiency Meter - A Preliminary Assessment of a Laboratory Model

ORNL/Sub-85/53142/1; 88 pp. (1987, September)

The objective of this project is to build a laboratory model of a combustion system seasonal efficiency meter (CSSEM) that is portable, easy to use and can determine both steady-state and seasonal efficiency of boilers and furnaces. The meter is microprocessor-based, receiving inputs from sensors connected to the combustion system under test and from keyboard entry data describing the system. Tests in the laboratory on a natural-gas-fired, forced-warm-air furnace indicated good agreement with the DOE-AFUE (Annual Fuel Utilization Efficiency) test procedure.

448
Pedersen, B.S., and W.J. Fisk, Lawrence Berkeley Laboratory, Berkeley, CA

An Experimental Study of Air Washing for the Removal of HCHO from Indoor Air

LBL-18874 (1985, November)

449

Perez-Blanco, H., and L. Pan, Oak Ridge National Laboratory, Oak Ridge, TN; University of North Carolina, Chapel Hill, NC

Comparative First- and Second-Law Analysis of an Absorption Cycle

ORNL/TM-9595 (1985, July)

Generally, the basis of efficiency calculations and optimization studies of absorption cycles is the first law of thermodynamics. This approach yields an efficiency parameter, the coefficient of performance (COP). It is often argued that a first-law analysis does not produce all the information needed to optimize the absorption system. According to this line of thought, only an analysis based on the second law of thermodynamics gives the needed information. The data needed for second-law analysis (i.e., for calculation of entropies and thermodynamic availabilities) are not readily available. For this reason, assessment of the usefulness of second-law analysis as applied to absorption cycles seems adequate to determine the potential benefits of gathering the additional data for the absorbent-refrigerant combinations currently under consideration. To this end, a comparative first- and second-law analysis of a single-effect, lithium bromide-water absorption cycle is carried out. An existing computer program and entropy values from the literature are used to analyze the cycle. The effects of temperature approaches in each heat exchanger and external heating/cooling fluid flow rates on the cycle performance are determined. A comparison of the results obtained via first- and second-law analyses reveals that the usefulness of the information depends on the boundaries of the system under consideration.

450

Perez-Blanco, H., and M.R. Patterson, Oak Ridge National Laboratory, Oak Ridge, TN

Conceptual Design and Optimization of a Versatile Absorption Heat Transformer

ORNL/TM-9841 (1986, June)

This report contains the theoretical results supporting the answers to some questions on heat exchangers. The choice of a solution of sodium hydroxide water for this study was based on two facts: the solution does have a wide solution field, and its properties are well known. The six-heat-exchanger heat transformer is modeled in a digital computer, and this model is coupled to an optimizer. The optimizer allocates the heat exchanger size among the various heat pump components to produce a minimum payback period. The results show that when the waste heat and the heat rejection temperatures are low, sodium hydroxide, water shows operational advantages over lithium bromide water. Otherwise, lithium bromide water can be employed with basically the same results. The optimization results show relatively short payback periods (1 to 2 years), which indicate that the cycle is worthy of further study and experimentation. The design of absorption cycles via optimization techniques saves significant time and effort in specifying heat exchangers for a given set of desired operating conditions.

451

Perry, A.M., Oak Ridge National Laboratory, Oak Ridge, TN

Environmental Effects of Chlorofluorocarbons: Will Restrictions Be Needed?

ORNL/TM-9817 (1986, October)

This report describes a method that has been devised for estimating ozone depletion for various assumptions regarding the future release of chlorocarbons (CLCs) to the atmosphere. The method is calibrated against published results obtained with more elaborate models of atmospheric chemistry and is applied for various scenarios for future CLC emissions, with and without emission controls. Estimates are also made of the climatic effects of CLC emissions, as represented by the average surface temperature of the earth. It is concluded that current rates of emission present no immediate danger to the earth and its inhabitants and would not do so for many decades.

452
Persily, A.K., National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Ventilation Efficiency in Mechanically Ventilated Office Buildings

NBSIR-85-3208 (1985, August)

453
Persily, A.K., and R.A. Grot, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

The Airtightness of Office Building Envelopes

(1986, March)

454
Persily, A.K., and R.A. Grot, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Ventilation Measurements in Large Office Buildings

PBG-87-153821; ASHRAE Journal 26(5):55 (1984)

Ventilation rates were measured in nine office buildings using an automated tracer gas measurement system. The buildings range in size from a two-story federal building with a floor plan of 2000 sq m to a 26-story building with a floor area of 64,000 sq m. Ventilation rates were measured for about one hundred hours in each building; results are presented and examined with a variation of time and weather.

455
Persily, A.K., W.A. Turner, H. Burge, and R.A. Grot, National Bureau of Standards, Washington, DC

Investigation of a Washington, DC Office Building

Special Technical Publication 1002:35 (1989)

This paper describes the techniques used to study a Washington, D.C. office building with a long history of indoor air quality and thermal comfort complaints. More than twenty investigations, mostly relatively short term, have been conducted since 1978 to determine the causes of the building's problems and to recommend corrective actions. More recently a long term, intensive study of the building has been undertaken to study the building more thoroughly and to investigate the application of several techniques for studying office building air quality. These techniques include tracer gas measurements of air exchange rates, ventilation system performance and ventilation effectiveness, and measurements of the levels of various indoor pollutants including bioaerosols.

456
Persoff, P., and A.T. Hodgson, Lawrence Berkeley Laboratory, Berkeley, CA

Correction for External Mass Transfer Resistance in Diffusive Sampling

LBL-18321; American Industrial Hygiene Association Journal 46(11):648 (1985, November)

An important source of error inherent in diffusive sampling is depletion of the analyte in the region around the open end of the sampler. Error due to depletion occurs when external mass transfer resistance is significant compared with the sampler's internal mass transfer resistance. A simple method to correct this error is presented. Multiple diffusive samplers of differing lengths are exposed simultaneously. A plot of calculated concentration of the analyte at the open end of the samplers versus diffusive flux is extrapolated to a sampler of infinite length, yielding an estimate of concentration in the bulk atmosphere. This method was demonstrated with a diffusive sampler for water vapor by comparing extrapolated concentrations of water vapor with concentrations measured with a dew-point hygrometer.

457
Petersen, S.R., National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Economic Insulation Levels for New and Existing Houses by Three-Digit Zip Code Users Guide and Reference Manual

ORNL/TM-11009; 44 pp.; NISTIR-88-3801 (1989, January)

ZIP Version 1.0 (the ZIP-Code Insulation Program) is a computer program developed to support the DOE Insulation Fact Sheet by providing users with customized estimates of economic levels of residential insulation for any location in the United States, keyed to the first three digits of its ZIP Code. The program and supporting files are contained on a single 5-1/4-inch diskette for use with microcomputers having an MS-DOS operating system capability. The ZIP program currently calculates economic levels of insulation for attic floors, exterior wood-frame and masonry walls, floors over unheated areas, slab floors, and basement and crawlspace walls. The economic analysis can be conducted for either new or existing houses.

458
Phillips, B.A., Phillips Engineering Company, St. Joseph, MI

Analyses of Advanced Residential Absorption Heat Pump Cycles

CONF-841231; Research and Development on Heat Pumps for Space Conditioning Applications, Proceedings of the DOE/ORNL Heat Pump Conference, Washington, DC, December 10, 1984; (pp. 265-287) (1985, August)

The overall purpose of this project is to develop a gas fired absorption heat pump for residential and small commercial applications that will produce a coefficient of performance of at least 1.6 Btu heating and 0.7 Btu of cooling per Btu of gas input. Being for residential operation, these goals refer to air-to-air heat pump operation at the rating conditions of 47 F outdoor ambient in heating mode and 95 F ambient in cooling mode. For year-round residential and small commercial use other requirements were added. One was that the heat pump itself be able to provide all the heating and cooling required by the building over the majority of temperatures experienced in the U.S. (from -10 F to 110 F) without resource to supplemental heat. It should also be potentially competitive with existing space conditioning products in cost, reliability, operating life, etc. The heat pump should be capable of meeting all national codes for residential installation. Due to the limitations of existing absorption fluid pairs, this requirement has made it necessary that air cooled absorption systems be outdoor products and that the heating and/or cooling effect be transferred to the conditioned space by means of a suitable secondary fluid. The additional temperature drops required for that heat transfer reduce the system coefficients of performance somewhat.

459
Piette, M.A., D. Flora, and S. Crowder, Lawrence Berkeley Laboratory, Berkeley, CA; Pacific Northwest Laboratory, Richland, WA

Energy-Efficient New Commercial Buildings in the Northwest Region: A Compilation of Measured Data

LBL-19293; 30 pp. (1985, March)

Data have been collected and analyzed for 36 new commercial buildings designed to be energy-efficient in the Northwest. Eighteen buildings are offices; the remainder are mostly retail buildings, and schools. The data were collected and analyzed to evaluate the building energy standards adopted by the Northwest Power Planning Council in the Northwest Conservation and Electric Power Plan. Almost half of the buildings are operating at energy levels under the Council's estimates for new efficient commercial buildings. There is, however, a large range of energy intensities. The average office building consumes 54 kBtu/sq ft/yr (in site energy units), while the average small office uses only 43 kBtu/sq ft/yr. Energy consumption for the eight retail buildings ranges from 47 kBtu/sq ft/yr to 134 kBtu/sq ft/yr.

460
Piette, M.A., and R. Riley, Lawrence Berkeley Laboratory, Berkeley, CA

Energy Use and Peak Power for New Commercial Buildings from the BECA-CN Data Compilation: Key Findings and Issues

LBL-20896; 40 pp.; CONF-860303; ET '86, Proceedings of the 13th Annual Energy Technology Conference and Exposition, Washington, DC, March 17, 1986 (1986, March)

Data have been collected and analyzed for 152 new commercial buildings from the U.S. and abroad. Each building has some energy-saving or load-shaping features, including techniques such as solar heating and cooling, thermal storage, load management, daylighting, efficient HVAC, and sophisticated control strategies. The data base covers energy and cost data, architectural and system characteristics, building operations, and special features. In this paper, quantitative parameters covering energy use, peak demand, occupancy, operating conditions, construction costs, and energy costs are discussed. About two-thirds of the buildings are offices. The average BECA-CN office uses 66 kBtu/sq ft/yr, which is about half the national office stock average. Measured energy use for these efficient buildings is roughly comparable to computer predictions for buildings designed to comply with the new ASHRAE Standard 90.1P. The average maximum peak electric demand is 5.5 W/sq ft for the offices. Peak demand charges account for about 20 to 30% of annual electricity charges. Energy costs an average of $1.02/sq ft/yr (in 1985 dollars) for the offices.

461
Piette, M.A., L.W. Wall, and B.L. Gardiner, Lawrence Berkeley Laboratory, Berkeley, CA

Measured Energy Performance of Energy-Efficient New Commercial Buildings: Results from the BECA-CN Data Compilation

LBL-19413 (1985, April)

Data was collected and analyzed for 36 new commercial buildings designed to be energy-efficient in the Northwest. Eighteen buildings were offices; the remainder, retail buildings and schools. The data were collected and analyzed to evaluate the building energy standards adopted by the Northwest Power Planning council in the Northwest Conservation and Electric Power Plan. Almost half of the buildings were operating at energy levels under the Council's estimates for new efficient commercial buildings, however, there were a large range of energy intensities. The average office building consumes 54 kBtu/sq ft/yr (in site energy units), while the average small office uses only 43 kBtu/sq ft/yr. The paper is organized into a discussion of data collection and manipulation procedures, analyses of the buildings' energy use and operating procedures and conclusions.

462
Piette, M.A., E. Wyatt, and J.P. Harris, Lawrence Berkeley Laboratory, Berkeley, CA

Technology Assessment: Thermal Cool Storage in Commercial Buildings

LBL-25521; 54 pp. (1988, January)

This report, one of a series of end-use energy technology assessment reports, investigates the current and potential use of thermal storage systems for cooling commercial buildings. The aim of these investigations is to synthesize current information from both published and unpublished resources so that utilities, state regulatory commissions, and others can better identify, evaluate, and select demand-site resources to meet their needs.

463
Pignone, C., J.H. Eto, and E. Kahn, Lawrence Berkeley Laboratory, Berkeley, CA

Corporate Planning Models as Least-Cost Utility Planning Tools

LBID-1148 (1986)

464
Prill, R.J., B.H. Turk, W.J. Fisk, D.T. Grimsrud, B.A. Moed, and R.G. Sextro, Lawrence Berkeley Laboratory, Berkeley, CA

Radon and Remedial Action in Spokane River Valley Homes - Volume 2

LBL-24638; 82 pp. (1987, December)

This collection of appendices supports the text in Volume I, Lawrence Berkeley Laboratory Report No. 23430. Volume II contains detailed information that is not contained in Volume I, including the following: (1) a description of radon measurement techniques; (2) a comprehensive chronology of house operating conditions, mitigation systems configurations and corresponding radon concentrations; (3) a summary of indoor and outdoor formaldehyde, water vapor, and respirable suspended particle concentrations, and ventilation rates; (4) a floor plan for each house detailing sampling sites and mitigation system installations; and (5) diagnostic maps of radon grab sampling.

465
Privon, G.T., Oak Ridge National Laboratory, Oak Ridge, TN

Engine-Driven and Absorption Heat Pump Programs

CONF-841231; Research and Development on Heat Pumps for Space Conditioning Applications, Proceedings of the DOE/ORNL Heat Pump Conference, Washington, DC, December 10, 1984; (pp. 211-214) (1985, August)

The objectives of these programs are to accelerate the development of energy-efficient, thermally activated heat pumps for heating and cooling. The internal combustion engine-driven heat pump program started in March 1980 with a subcontract to Honeywell, Inc., for technology development, fabrication, and testing of a commercial-size breadboard system utilizing a free-piston linear engine. At this time, one subcontractor (Tectonics Research) is actively continuing the efforts started in the Honeywell, Inc., project. Tectonics has progressed to the point where a breadboard system with a 32.5%-BHP-efficient linear engine is in the final phase of steady state performance testing. Three subcontractors, Carrier, Phillips, and Trane, are active in the absorption heat pump advanced cycle program. Each has completed analyses and has selected preferred cycles and fluids. All four projects involve a degree of technical risk. Reliability for the linear engine heat pump and long life of the shaft seal must be established. The advanced absorption systems each require high performance from an internal counterflow heat exchanger and the development of reliable, high-performance fluid pumps.

466
Prowler, D., E.J. Mohler, and M. Aseltine, Oak Ridge National Laboratory, Oak Ridge, TN

Inventory of Energy Research in Schools of Architecture 1972-1985

ORNL/Sub-84/89680/1; 83 pp. (1987, January)

This inventory was undertaken to summarize and analyze the funded building energy research conducted in schools of architecture during the period 1972 to 1985. Individual project information was sought from faculty in all the accredited schools of architecture in the United States and Canada through a mail inventory process. Principal Investigators were asked to complete an inventory form for each of their research projects describing the nature and contract value of each project. Seventy-five percent of the architecture schools responded to the request for information. From these institutions, data was collected on almost three hundred projects. This information was compiled using "dBase III" database software to provide three project summaries organized by schools, by principal investigators, and by key words. The key words were selected by the principal investigators from a list of key words included in the original inventory form. Using a series of programs written in the dBase III programming language, the data was also analyzed to provide insights into research topics, trends in research emphasis over the thirteen year period covered by the study, the extent of research funding, the institutional sources of funding and their topics of research preference, and levels of institutional and principal investigator involvement in energy research. Through these various analyses, the study provides a comprehensive overview of the role of architecture schools in recent building energy research.

467
Radermacher, R., University of Maryland, College Park, MD

Laboratory Experiments on Absorption Heat Pumps

CONF-841231; Research and Development on Heat Pumps for Space Conditioning Applications, Proceedings of the DOE/ORNL Heat Pump Conference, Washington, DC, December 10, 1984; (pp. 227-232) (1985, August)

A series of laboratory performance tests were conducted on an absorption cycle water chiller and heat pump. The part-load performance was compared to the full-load capacity and coefficient of performance. The causes of performance degradation with shorter operating times are speculated upon with partial substantiation resulting from tests on the chiller after it had been modified to prevent off cycle fluid migration.

468
Razgaitis, R., J.H. Payer, S.G. Talbert, B. Hindin, E.L. White, D.W. Locklin, R.A. Cudnik, and G. Stickford, Battelle Columbus Laboratories, Columbus, OH

Condensing Heat Exchanger Systems for Residential/Commercial Furnaces and Boilers - Phase IV

BNL-51943; 212 pp. (1985, October)

The development of condensing heat exchanger systems is studied. In the work reported here, the focus is on the corrosion resistance of materials to condensate produced by gas-fired heating equipment, and the characterization of the spatial variation of condensation corrosivity in condensing heat exchangers.

469
Reed, J.H., R.P. Broadwater, A. Chandrasekara, and J. Thompson, Oak Ridge National Laboratory, Oak Ridge, TN; Tennessee Technological University, Cookeville, TN

Patterns of Electric Water Heater Use and the Effects of Water Heater Load Control on Customers

CONF-880814; Energy Efficiency in Buildings, Proceedings of a Summer Study, Pacific Grove, CA, August 28-September 3, 1988; (13 pp.) (1988)

This paper reports on the analysis of the water heater load control experiments. Conducted as part of the Athens Automation and Control Experiment (AACE), the analysis is based on data from end-use monitoring devices as well as survey data. A total of 36 water heaters were monitored during the winter months of 1986/87.

470
Reilly, J.M., and S.A. Shankle, Pacific Northwest Laboratory, Richland, WA

Auxiliary Heating in the Residential Sector

PNL-SA-14252; 35 pp. (1986, August)

The prevalence of dual-fuel capabilities in the residential sector and estimates of the intensity of equipment use are examined in this paper. The Residential Energy Consumption Survey (RECS) data collected by DOE are utilized. Types of auxiliary and dual-fuel capability equipment, estimates of the intensity of auxiliary equipment use and suggestions for incorporating dual-fuel capabilities are examined.

471
Reilly, R.W., Pacific Northwest Laboratory, Richland, WA

Building Systems Integration Research: Recommendations for a U.S. Department of Energy Multiyear Program Plan

PNL-5696; 71 pp. (1986, January)

This plan describes the scope, technical content, and resources required to conduct the Building System Integration (BSI) research program during FY 1987 through 1991. System integration research is defined, the need for the research is discussed, its benefits are outlined, and the history of building system integration research is summarized. The program scope, the general approach taken in developing this program plan, and the plan's contents are also described.

472
Reilly, S., and D. Arasteh, Lawrence Berkeley Laboratory, Berkeley, CA

WINDOW 3.1: A Computer Tool for Analyzing Window Thermal Performance

LBL-25184; 7 pp.; CONF-880615; Solar '88, Proceedings of the American Solar Energy Society 1988 Annual Meeting and the 13th National Passive Solar Conference, Cambridge, MA, June 19-24, 1988 (1988, May)

WINDOW 3.1 is a public-domain computer program developed by the Windows and Daylighting Group at Lawrence Berkeley Laboratory for analyzing heat transfer through window systems. The program uses an iterative technique to calculate the one-dimensional temperature profile across a user-defined window system. From this data, window system performance indices (e.g., U-value, shading coefficient) are calculated. WINDOW 3.1, a major update to WINDOW 2.0, incorporates several technical additions and many new user-friendly features, and provides a consistent and versatile means for heat transfer analysis as did WINDOW 2.0. WINDOW 3.1 can vary environmental conditions, window tilt, number of glazing layers, layer properties (thermal infrared, solar and visible optical properties, and thermal conductance), gap widths, composition of gap gas fill, and spacer and frame materials. This paper presents an overview of the computational methodology, describes the capabilities of the program, and discusses the applications of WINDOW 3.1 for standardizing window heat transfer calculations and in designing new insulating window systems.

473
Reimann, R.C., Carrier Corporation, Syracuse, NY

Advanced Absorption Heat Pump Cycles

CONF-841231; Research and Development on Heat Pumps for Space Conditioning Applications, Proceedings of the DOE/ORNL Heat Pump Conference, Washington, DC, December 10, 1984; (pp. 259-261) (1985, August)

The main goal of this project is the development of significantly improved absorption machinery. This was to be directed specifically towards the development of a direct natural gas-fired absorption heat pump with both heating and cooling efficiencies advanced beyond current commercial offerings. These were to be accomplished through the use of novel and superior cycles or by improved component performance. To keep the focus on machinery, the stipulation was agreed that candidate absorbent-refrigerant combinations were to be selected from among those whose properties were adequately known to permit cycle calculations and preliminary machine layouts.

474
Reimann, R.C., and G. Melidan, Oak Ridge National Laboratory, Oak Ridge, TN

Development and Proof-Testing of Advanced Absorption Refrigeration Cycle Concepts - Phase 2

CONF-8804100; Research and Development on the Heat Pump for Space Conditioning Applications, Proceedings of the Second DOE/ORNL Heat Pump Conference, Washington, DC, April 17-20, 1988, 225 pp.; (7 pp.) (1988, July)

This paper summarizes the results of the work performed to date under Phase II of the DOE program. The Phase II objective is to design, fabricate, and proof-test a natural gas-fired absorption heat pump (AHP) with an efficiency level substantially higher than present day state-of-the-art equipment. To achieve these objectives, Carrier investigated the performance of the candidate Phase I fluids (lithium bromide:zinc bromide/methyl alcohol-MEOH or lithium bromide:water methylamine-MMA) as well as high concentration formulations of the conventional LiBr/H2O mixture for high temperature, upper loop use.

475
Rennex, B.G., National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

An Assessment of Needs for New Thermal Reference Materials

NBSIR-85-3146; 98 pp. (1985, April)

Thermal insulation specimens are required by users to calibrate their heat transfer apparatuses. This report assesses the need for additional calibration specimens to cover a wider range of test conditions and materials. It examines two major sources of measurement error related to the use of calibration specimens. The first is due to the lack of uniformity over a specimen area and the second is due to systematic apparatus errors which vary with the values of specimen mean temperature and thermal conductivity. Possible solutions to these problems are given, based on information obtained from users in universities, industry, and government laboratories. These include recommendations to provide calibration specimens over a wide range of values of specimen temperature and thermal conductivity.

476
Revzan, K.L., Lawrence Berkeley Laboratory, Berkeley, CA

Effectiveness of Local Ventilation in Removing Simulated Pollution from Point Sources

LBL-16701 (Rev.); Environment International 12(1-4):449-459; Indoor Air Quality and Climate, Proceedings of the Third International Conference, Stockholm, Sweden, August 20, 1984 (1984)

The influence of environmental conditions on the effectiveness of range hoods and window fans removing indoor pollutants is considered. Tests were conducted in a two-room test space whose infiltration rate was less than 0.1 h(E-1). Pollutants were simulated using dilute sulfur hexafluoride as a tracer gas. Range hood tests were carried out with heated and unheated tracer gas. In the former case, where the buoyancy of the tracer was fixed, removal efficiency was roughly linear over a range of flow rates from 10.3 to 60.0 L s(E-1); the highest measured efficiency was 0.77. With unheated tracer gas, effectiveness was highly dependent on free convection patterns, so that the concept of ventilation efficiency was inapplicable. Window fan tests were conducted with the source of tracer gas in each of the two rooms, the fan itself remaining fixed. The results demonstrate the difficulty of applying conventional definitions of ventilation efficiency, such as those derived from mass-balance models, to realistic situations.

477
Revzan, K.L., A.V. Nero, and R.G. Sextro, Lawrence Berkeley Laboratory, Berkeley, CA

Mapping Surficial Radium Content as a Partial Indicator of Radon Concentrations in U.S. Houses

LBL-24344; 12 pp.; CONF-871208; The Natural Radiation Environment, Proceedings of the Fourth International Symposium, Lisbon, Portugal, December 7, 1987 (1987, December)

The use of a database developed from the National Aerial Radiometric Reconnaissance in the development of a map of radium in soil for the contiguous 48 states is discussed. Authors examine the relationship between the results of measurements of radon in houses and the indications of the U.S. map, noting that some, but by no means all, of the areas known to have elevated radon concentrations appear as areas of higher radium concentration than their surroundings and that there are other areas, in which measurements of high radon levels have not been made, which are suggested as deserving of interest. A discussion of mapping techniques for smaller areas and possible methods of dealing with apparent discrepancies between adjacent areas is included. On a national basis, as much as half the variation in radon from region to region may be accounted for by the level of radium in the soil according to researchers, but study indicates that there are regions for which the radium concentration does not account for the relatively high observed radon.

478

Revzan, K.L., B.H. Turk, J. Harrison, A.V. Nero, and R.G. Sextro, Lawrence Berkeley Laboratory, Berkeley, CA

Parametric Modelling of Temporal Variations in Radon Concentrations in Homes

LBL-24179; 21 pp.; CONF-871006; Proceedings of the 34th Nuclear Science Symposium and the 19th Nuclear Power Systems Symposium, San Francisco, CA, October 21, 1987; IEEE Transactions on Nuclear Science 35(1):550-555 (1988, January)

The Rn-222 (radon) concentrations in the living area, the basement, and the underlying soil of a New Jersey home have been measured at half-hour intervals over the course of a year, as have indoor and outdoor temperatures, wind speed and direction, and indoor-outdoor and basement-subslab pressures; in addition, periods of furnace operation have been logged. Author generalize and extends an existing radon entry model in order to demonstrate the dependence of the radon concentrations on the environmental variables and the extent of furnace use. The model contains parameters which are dependent on geological and structural factors which have not been measured or otherwise determined; statistical methods are used to find the best values of the parameters. The non-linear regression of the model predictions (over time) on the measured living area radon concentrations yields an R2 of 0.88.

479

Rice, C.K., Oak Ridge National Laboratory, Oak Ridge, TN

Capacity Modulation Component Characterization and Design Tool Development - Washington, DC

CONF-8804100; Research and Development on the Heat Pump for Space Conditioning Applications, Proceedings of the Second DOE/ORNL Heat Pump Conference, Washington, DC, April 17-20, 1988, 225 pp.; (12 pp.) (1988)

This effort has been focused on obtaining and evaluating modulating component and drive performance data for electric-driven, air-to-air residential heat pumps. The modulating performance data were obtained for purposes of: establishing a technology base for modulating components; providing a foundation for modulating model development; and screening compressor and drive types to be used in modulating system design assessments. For the screening analyses, the relative performance of various compressors and drives was evaluated under appropriate modulating conditions.

480

Rice, C.K., and S.K. Fischer, Oak Ridge National Laboratory, Oak Ridge, TN

A Comparative Analysis of Single- and Continuously-Variable Capacity Heat Pump Concepts

CONF-841231; Research and Development on Heat Pumps for Space Conditioning Applications, Proceedings of the DOE/ORNL Heat Pump Conference, Washington, DC, December 10, 1984; (pp. 57-65) (1985, August)

An initial assessment of the potential benefits of continuous-capacity-modulation in electric-driven, air-to-air heat pumps for residential application is presented. The purpose of the project was to provide a quantitative estimate of the possible annual performance gains of advanced continuously modulating heat pumps relative to single-speed designs at comparable levels of development. The present work represents an extension of the earlier work in two directions. First, seasonal (heating and cooling) and annual performance factor (APF) analysis capability was added to allow direct evaluation of annual energy use from heat pump performance data generated by the ORNL heat pump model. Secondly, a modulating version of the heat pump model was developed to provide a means for simulating the steady state performance of continuously variable-speed (CVS) systems. With these tools, the APFs of both single- and continuously variable-capacity (CVC) concepts could be studied as basic heat pump design variables were varied.

481
Richardson, R.W., and S. Berman, Lawrence Berkeley Laboratory, Berkeley, CA

Determination of the Excited State Density of an Optically Thick Resonance Line

LBL-21475; 17 pp.; CONF-8604388; The Science and Technology of Light Sources, Proceedings of the Fourth International Symposium, Karlsruhe, Federal Republic of Germany, April 7, 1986 (1986, April)

The transverse profile of the monochromatic radiance of an optically thick resonance line from a cylindrical discharge is inverted exactly to give the radial distribution of radiating atoms. In contrast to the Abel transform, this result is valid for all optical depths.

482
Ritschard, R.L., Y.J. Huang, S. Byrne, I. Turiel, and J. Bull, Lawrence Berkeley Laboratory, Berkeley, CA

PEAR: A Microcomputer Program for Residential Energy Analysis

LBL-20355; 15 pp.; CONF-850817; Building Energy Simulation, Proceedings of a Conference, Seattle, WA, August 21, 1985 (1985, November)

A description of a software package called PEAR (Program for Energy Analysis of Residences) which was written with user-friendly input and output and runs on the IBM PC, is presented. PEAR provides an easy-to-use and very fast compilation and extrapolation of a comprehensive DOE-2.1 database for residential buildings. The current version, which covers five residential building prototypes in over 800 locations, estimates energy and cost savings resulting from typical conservation measures such as ceiling, wall and floor insulation, window type and glazing layers, infiltration levels, and equipment efficiency. It also allows the user to adjust for optional measures including roof or wall color, movable insulation, whole-house fans, night temperature setback, reflective or heat absorbing glass, thermal mass in exterior walls, and two attached sunspace options. The program is designed to be used both as a research tool by energy and policy analysts, and as a non-technical energy calculation method by architects, home builders, home owners and others in the building industry.

483
Ritschard, R.L., Y.J. Huang, and D.J. Wilson, Lawrence Berkeley Laboratory, Berkeley, CA

Attached Sunspaces as Energy Savers

LBL-20274 (1985, January)

484
Roop, J.M., Pacific Northwest Laboratory, Richland, WA

Draft Economic Analysis: Proposed Interim Energy Conservation Standard for Design of New Federal Commercial Buildings

PNL-5120 (1985, June)

485
Roop, J.M., D.B. Belzer, and A.A. Bohn, Pacific Northwest Laboratory, Richland, WA; Argonne National Laboratory, Argonne, IL

Comparative Analysis of Energy Data Bases for the Industrial and Commercial Sectors

PNL-5621; 100 pp. (1986, December)

A comparative analysis of energy data bases in two of the four major end-use sectors is defined by the Department of Energy, the industrial and commercial sectors in this report. This report is the product of a joint effort conducted by Argonne National Laboratory and Pacific

Northwest Laboratory (PNL) for the Office of Minority Impacts and the Office of Policy Integration of the U.S. Department of Energy. The comparative analyses of the residential and (personal) transportation data bases were conducted at Argonne, the commercial and industrial sector assessments at PNL. The analysis is undertaken from the perspective of the policy analyst. Accordingly, the sources, time periods, unit of analysis, method of collection, extensiveness, and reliability are examined for each major data source. This information forms the basis for assessing the strengths and weaknesses of the data, how to use the data, and how to improve the data sources.

486
Rosenfeld, A.H., Lawrence Berkeley Laboratory, Berkeley, CA

Shifting Peak Power: At the Meter, Beyond the Meter, and at the Checkbook

LBL-19135 (1985, May)

487
Rosenfeld, A.H., Lawrence Berkeley Laboratory, Berkeley, CA

Residential Energy Efficiency: Progress Since 1973 and Future Potential

LBL-20506; 33 pp.; CONF-8504174; Energy Sources: Conservation and Renewables, Proceedings of a Conference, Washington, DC, April 27, 1985 (1985, August)

Today's 85 million U.S. homes use $100 billion of fuel and electricity ($1150/home). If their energy intensity (resource energy/sq ft) were still frozen at 1973 levels, they would use 18% more. With well-insulated houses, need for space heat is vanishing. Superinsulated Saskatchewan homes spend annually only $270 for space heat, $150 for water heat, and $400 for appliances, yet they cost only $2000 plus or minus $1000 more than conventional new homes. The concept of Cost of Conserved Energy (CCE) is used to rank conservation technologies for existing and new homes and appliances, and to develop supply curves of conserved energy and a least cost scenario. Calculations are calibrated with the BECA and other data bases. By limiting investments in efficiency to those whose CCE is less than current fuel and electricity prices, the potential residential plus commercial energy use in 2000 AD drops to half of that estimated by DOE, and the number of power plants needed drops by 200. For the whole buildings sector, potential savings by 2000 are 8 Mbod (worth $50B/yr), at an average CCE of $10/barrel.

488
Rosenfeld, A.H., D.A. Bulleit, and R.A. Peddie, Lawrence Berkeley Laboratory, Berkeley, CA

Smart Meters and Spot Pricing: Experiments and Potential

LBL-20507 (1986)

489
Rosenfeld, A.H., and O. de la Moriniere, Lawrence Berkeley Laboratory, Berkeley, CA

The High Cost-Effectiveness of Cool Storage in New Commercial Buildings

LBL-19448; CONF-850606; Proceedings of the Semiannual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Honolulu, HI, June 23-26, 1985; ASHRAE Transactions 91(2B):818-834 (1985, June)

In new commercial buildings with demand meters, thermal storage is already cost-effective. The cheapest strategy, partial storage, displaces two-thirds of cooling demand and can displace 3 GW each year in new U.S. buildings. The more expensive strategy of full-demand avoidance can shift another 2 GW. Partial storage uses a chiller, sized to run continuously. On a summer night, the excess chiller capacity goes to storing coolth, then the next afternoon this coolth is used to supplement the chiller. This strategy requires the smallest capacity chiller and the smallest volume storage, i.e., the least first cost. Demand-limited storage minimizes cost of operation by installing a somewhat larger chiller, sized to be able to turn off when power is most expensive. Both chiller and storage must be about 40% larger than what is required for partial storage. Many builders will go only as far as partial storage, which has a payback of less than three years. But from the point of view of society and the utilities, full-peak avoidance will in the long run save money and power plants. We discuss the attractiveness of both strategies for the customer and for the utilities.

490
Rosenfeld, A.H., and D. Hafemeister, Lawrence Berkeley Laboratory, Berkeley, CA

Energy Conservation in Large Buildings

LBL-20505; 25 pp.; CONF-8504174; Energy Sources: Conservation and Renewables, Proceedings of a Conference, Washington, DC, April 27, 1985 (1985, August)

As energy prices rise, newly energy aware designers use better tools and technology to create energy efficient buildings. Thus the U.S. office stock (average age 20 years) uses 250 kBtu/sq ft of resource energy, but the guzzler of 1972 uses 500 (up x 2), and the 1986 ASHRAE standards call for 100 to 125 (less than 25% of their 1972 ancestors). Surprisingly, the first real cost of these efficient buildings has not risen since 1972. Scaling laws are used to calculate heat gains and losses of buildings to obtain the delta T(free) which can be as large as 15 to 30 C (30 to 60 F) for large buildings. The net thermal demand and thermal time constants are determined for the Swedish Thermodeck buildings which need essentially no heat in the winter and no chillers in summer. The BECA and other data bases for large buildings are discussed. Off-peak cooling for large buildings is analyzed in terms of saving peak-electrical power. By downsizing chillers and using cheaper, off-peak power, cost-effective thermal storage in new commercial buildings can reduce U.S. peak power demands by 10 to 20 GW in 15 years. A further potential of about 40 GW is available from adopting partial thermal storage and more efficient air conditioners in existing buildings.

491
Rosenfeld, A.H., and M.D. Levine, Lawrence Berkeley Laboratory, Berkeley, CA

Statement on the Least Cost Utility Planning Initiative

EEB-85-5 (1985)

492
Rosenfeld, A.H., and M.E. Verdict, Lawrence Berkeley Laboratory, Berkeley, CA; Texas Public Utility Commission, Austin, TX

Avoided Gigawatts Through Utility Capital Recovery Fees and Marginal Cost Pricing of Electricity

LBL-20557; 11 pp.; CONF-860818; Energy Efficiency in Buildings, Proceedings of the American Council for an Energy Efficient Economy Santa Cruz Summer Study, Santa Cruz, CA, August 17, 1986 (1986, June)

Advances in building technologies and appliance efficiencies have the combined potential to save up to 50% of the electricity demand of new buildings. This paper will discuss the advantages and disadvantages of using capital recovery fees for utility hookups and marginal cost pricing of electricity to defer the construction of more than 100 GW of peak power capacity power plants over the next 20 to 40 years, saving $10 to 20 billion per year in reduced electricity bills to consumers.

493
Rossiter, W.J., National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

The Effects of Application Parameters on Adhesive-Bonded Seams in Single-Ply Membranes

CONF-8509137; Roofing Technology, Proceedings of the Second International Symposium, Chicago, IL, September 19, 1985 (1985)

494
Rossiter, W.J., National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

A Methodology for Assessing the Thermal Performance of Low-Sloped Roofing Systems

NBSIR-85-3264 (1986, May)

495
Rossiter, W.J., W.C. Cullen, and R.G. Mathey, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Roof Management Programs

NBSIR-85-3239 (1985)

496
Rossiter, W.J., W.C. Cullen, and R.G. Mathey, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

U.S. Postal Service Roofing Practices

NBSIR-85-3275 (1985)

497
Rossiter, W.J., and R.G. Mathey, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Weatherization of Residences: Criteria for Thermal Insulation

Journal of Thermal Insulation 8 (1986)

498
Rossiter, W.J., and R.G. Mathey, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Weatherization of Residences: Criteria for Retrofit Materials and Products

NBS/TN-1201; 71 pp. (1984, August)

The Department of Energy (DOE) requested the National Bureau of Standards to review and update criteria for materials and products to be included in the DOE Weatherization Assistance Program. This Program was established by Congressional legislation in 1976 and was directed toward providing financial assistance to low-income individuals for retrofitting residences to conserve energy. In most cases, only energy-saving materials and products for which standards and specifications are available are to be included in the Program. In late 1983 DOE proposed rule changes to the Program which made it necessary to update existing criteria and establish, as appropriate, new criteria. Criteria are given for retrofit materials and products included in the DOE Weatherization Assistance Program. These materials and products are thermal insulation, storm windows and doors, replacement windows and doors, caulks and sealants, weatherstripping, vapor retarders, clock thermostats, and replacement glazing. The criteria are based on a consideration of factors such as thermal performance, fire safety, durability, quality, conformance to building codes, use, and ease of installation. The retrofit materials and products are listed by generic type along with pertinent standards and specifications. Precautions to be followed during their installation are also given for each of the items. Fire safety requirements for thermal insulations are recommended with regard to the use and locations where they are installed.

499
Rossiter, W.J., and R.G. Mathey, National Bureau of Standards, Washington, DC

Urea-Formaldehyde Foam Insulations: A Review of Their Properties and Performance

NBS/TN-1210; 73 pp. (1985, March)

Urea-formaldehyde foam insulation was commonly used in the mid-to-late 1970s for retrofitting the sidewalls of residences. Many reports describing the use of this material in buildings have been published. This report presents a review of the properties and performance of urea-formaldehyde foams pertinent to their use as thermal insulation for buildings. The review is based primarily on existing published literature. The factors affecting the performance of these insulations are listed and discussed. Included among these factors are durability, effect on energy conservation, effect on other building materials, fungus resistance, shrinkage, and temperature and humidity effects on foam. A key issue involving the use of urea-formaldehyde foam insulation is its release of formaldehyde, other gases, and particulates into the air of residences. Information concerning the release of these agents is summarized. The literature evidence indicates that where formaldehyde measurements have been made, on the average, formaldehyde levels in homes with foam insulation are higher than those without foam. The mechanism of formaldehyde release from foams is not totally understood. A review of remedial actions which may be taken to reduce or eliminate formaldehyde release from foams into residences is given. The information concerning the remedial actions discussed are those primarily being used in Canada. In addition, standards for urea-formaldehyde foam insulations developed in North America and Europe were reviewed and the material property requirements tabulated. The standards do not contain requirements pertaining to the long-term release of formaldehyde from these foam insulations.

500

Rossiter, W.J., and R.G. Mathey

Magnesium Oxychloride Cement-Based Foam Insulation: A Review of Available Information and Identification of Research Needs

NBSIR-86-3326 (1986, June)

501

Rubinstein, F.M., T.A. Clark, M.J. Siminovitch, and R. Verderber, Lawrence Berkeley Laboratory, Berkeley, CA

The Effect of Lighting System Components on Lighting Quality, Energy Use, and Life-Cycle Cost

LBL-21884; 8 pp.; CONF-860903; Proceedings of the IEEE-Industry Applications Society Annual Meeting, Denver, CO, September 28, 1986 (1986, July)

A computational method was developed to examine the effect of lamp, ballast, and fixture selection on the quality and quantity of illumination, energy consumption, and life-cycle cost of lighting systems. Applying this analysis to lighting layouts using different lamp/ballast/fixture combinations suggested that combinations with higher lumen outputs reduced the uniformity of the illuminance distribution at the workplace but did not reduce visibility levels. The use of higher lumen output lamp/ballast/fixture systems and higher efficiency components tended to reduce life-cycle costs as long as the premium cost of the components was not too high according to researchers.

502

Ruderman, H., Lawrence Berkeley Laboratory, Berkeley, CA

A Consumer Demand Model for Analyzing the Effects of Efficiency Standards on Appliance Choice and Residential Energy Consumption

LBL-19589 (1985, May)

503

Ruderman, H., M.D. Levine, and P. Chan, Lawrence Berkeley Laboratory, Berkeley, CA

The Effect of Energy Conservation Measures on Residential Electricity Demand and Load Shape

LBL-21099; 15 pp.; CONF-860818; Energy Efficiency in Buildings, Proceedings of the American Council for an Energy Efficient Economy Santa Cruz Summer Study, Santa Cruz, CA, August 17, 1986 (1986, August)

A method has been developed for calculating changes in annual electricity consumption and hourly loads in the residential sector resulting from the implementation of one or more energy conservation measures in a utility service area. The methodology was used to evaluate different measures by comparing their impacts in three service areas with differing load characteristics. The measures included improvements to the thermal integrity of the building, increased appliance efficiencies, as well as combinations of these measures. Three service areas were selected that differed widely in their climatic conditions, appliance saturations, and other household characteristics. The conservation measures were evaluated by comparing their impacts on electricity sales and on peak summer and winter loads.

504
Ruderman, H., M.D. Levine, and J.E. McMahon, Lawrence Berkeley Laboratory, Berkeley, CA

The Behavior of the Market for Energy Efficiency in Residential Appliances including Heating and Cooling Equipment

LBL-15304 (1987, January)

505
Schepper, L., A. Ketoff, S. Meyers, and D. Hawk, Lawrence Berkeley Laboratory, Berkeley, CA

Residential Electricity Consumption In Industrialized Countries: Changes Since 1973

Energy 12(12):1197 (1987)

The evolution of residential electricity use since the early 1970s in 11 OECD countries is considered. Average growth in demand has been higher in Europe and Japan than in the United States. According to authors, this is mainly attributable to the difference in saturation of appliances and electricity heating, which was higher in the U.S. than elsewhere at the beginning of the period. Growth in appliance ownership was responsible for high growth rates from 1960 through around 1973, when electric heating began to become popular in may countries. By the early 1980s, more efficient appliances and tighter new homes dampened growth in demand in most countries. Average growth in electricity demand per household between 1978 and 1983 was generally less than 2% per yr, and was negative in some countries.

506
Schlegel, J.A., D.C. Hewitt, L.A. O'Leary, and L.N. McCold, Wisconsin Energy Conservation Service, Madison, WI

Improving Infiltration Control Techniques in Low Income Weatherization

DOE/CE/27460-T25; Energy Efficiency in Buildings: Volume 2 - Small Building Technologies, Proceedings of the American Council for an Energy Efficient Economy Santa Cruz Summer Study, Santa Cruz, CA, August 17, 1986; (pp. 2.260-2.272) (1986, August)

Infiltration control technologies have been the most frequently applied energy conservation measure in low-income weatherization programs. The common approach has typically utilized weatherstripping and exterior caulking in conjunction with window repair. In an effort to reduce costs while increasing effectiveness, a different approach to infiltration control was tested. A blower door was used to locate actual leakage sites. Time and level of effort guidelines were developed based on pre-retrofit air changes at 50 pascals depressurization (ACH50) to assist the weatherization crew in making work judgments. Two different methods for incorporating blower doors into the weatherization program were tested. One group of 18 houses received infiltration control work only, with an average expenditure of $106 in labor and materials, about 19% of the amount typically spent in Wisconsin. The other group of 31 houses received an average of $147 in infiltration related work in addition to other weatherization measures. Air change rates (ACH50) in both of the groups were reduced by about 15%, with 31% of the houses receiving no specific infiltration control work. The low-income houses in the study had lower pre-retrofit air change rates than anticipated (9.6 ACH50 average). The results indicated that use of a blower door and related field management procedures could lead to increased predictability of the effectiveness of infiltration control and that costs of infiltration work could be reduced while still significantly reducing air leakage in the house.

507
Schreiber, J.G., Lewis Research Center, Cleveland, OH

Initial Results of Sensitivity Tests Performed on the RE-1000 Free-Piston Stirling Engine

CONF-841231; Research and Development on Heat Pumps for Space Conditioning Applications, Proceedings of the DOE/ORNL Heat Pump Conference, Washington, DC, December 10, 1984; (pp. 171-179) (1985, August)

A 1 kW (1.33 hp) single cylinder free-piston Stirling engine has been tested in the test facilities at the Lewis laboratory. Tests have been performed over the past several years on an engine designed to investigate the dynamics of a free-piston Stirling engine for the purpose of computer code validation. Tests to investigate the sensitivity of the engine performance to variations in working space pressure, heater and cooler temperatures, regenerator porosity, power piston mass and displacer dynamics have been initiated at Lewis. Maps of engine performance have been recorded with the use of an 81.2% porosity regenerator; both a high efficiency displacer and a high power displacer were tested; efficiencies up to 33% were recorded and power output of approximately 1500 watts was recorded. Preliminary results from the sensitivity tests being performed on the RE-1000 free-piston Stirling engine are presented. Descriptions of future tests are also given.

508
Schwehr, M.B., Lawrence Berkeley Laboratory, Berkeley, CA

A Quantitative Health-Risk Assessment of Indoor Air Pollutants

LBL-21512 (1985, May)

509
Selkowitz, S., Lawrence Berkeley Laboratory, Berkeley, CA

The Application of Daylighting Research Tools to Fenestration and Building Design Optimization

LBL-19167; 12 pp.; CONF-8503101; Research and Design '85, Proceedings of a Conference, Los Angeles, CA, March 14, 1985 (1985, February)

It is commonplace in both the building research and design communities to separate the two endeavors and accentuate the differences between them. We often hear that the researchers' tools and approaches are not useful for design purposes; they are too slow, and too complex, and while they generate quantities of fate, they provide little useful information. While this will often be true, there are significant cases where it is not so. By exploring these in more detail we can learn about the complementary nature of research and design.

510
Selkowitz, S., Lawrence Berkeley Laboratory, Berkeley, CA

Window Performance and Building Energy Use: Some Technical Options for Increasing Energy Efficiency

LBL-20213; 16 pp.; CONF-8504174; Energy Sources: Conservation and Renewables, Proceedings of a Conference, Washington, DC, April 27, 1985 (1985, June)

Window system design and operation has a major impact on energy use in buildings as well as on occupants' thermal and visual comfort. Window performance will be a function of optical and thermal properties, window management strategies, climate and orientation, and building type and occupancy. In residences, heat loss control is a primary concern, followed by sun control in more southerly climates. In commercial buildings, the daylight provided by windows may be the major energy benefits but solar gain must be controlled so that increased cooling loads do not exceed daylighting savings. Reductions in peak electrical demand and HVAC system size may also be possible in well-designed daylighted buildings.

511
Selkowitz, S., Lawrence Berkeley Laboratory, Berkeley, CA

The Impact of Daylighting Strategies on Electric Utilities

LBL-21919; CONF-861109; Architecture and Natural Light, Proceedings of the Second International Daylighting Conference, Long Beach, CA, November 5-7, 1986; (p. 244) (1986, November)

512
Selkowitz, S., K. Papamichael, and G.M. Wilde, Lawrence Berkeley Laboratory, Berkeley, CA

A Concept for an Advanced Computer-Based Building Envelope Design Tool

LBL-20545; 10 pp.; CONF-861109; Architecture and Natural Light, Proceedings of the Second International Daylighting Conference, Long Beach, CA, November 5-7, 1986 (1986, November)

A review of current daylighting design tools indicates that over 30 tools are now available, including nomographs, protractors, overlays, and programs for micro-, mini-, and mainframe computers. Computer-based tools allow testing and analyzing of more design alternatives under a wider variety of conditions than was previously practical with slower techniques, but they have not fundamentally changed the information available to the design professional. These tools are applicable to certain limited functions of the design process and do not address the varying information needs of the designer at various points in the design process. We describe a concept for a computer-based building envelope design tool that is structured to overcome many of the limitations of the existing tools. The tool would address daylighting design in the context of the overall building envelope design, covering a range of environmental quality issues in addition to quantitative aspects of lighting and energy use. It would be useful throughout the process of design, construction, and occupancy, and is intended to provide important feedback that is often missing between those stages of the building's life cycle. A cost-effective tool with these performance features is not technically feasible using today's hardware technology. However, examination of the development of the necessary technologies provides strong evidence for future feasibility; accordingly, we are developing the tool to be used in a 1990 plus time frame. To date we have studied the features and capabilities that such a tool should have, as well as several key areas, such as the design process, computer graphics, imaging systems, expert systems, and building science data bases.

513
Selkowitz, S., and J. Spear, Lawrence Berkeley Laboratory, Berkeley, CA

New Approaches to the Photometry of Fenestration Systems and their Optical Components

LBL-20537; CONF-861109; Architecture and Natural Light, Proceedings of the Second International Daylighting Conference, Long Beach, CA, November 5-7, 1986 (1986, November)

514
Selkowitz, S., S.A. Sullivan, J. Hayes, and A. Wilson, Lawrence Berkeley Laboratory, Berkeley, CA

Analysis of Window Performance in a Single-Family Residence

LBL-18247; 8 pp.; CONF-840954; Proceedings of the Ninth National Passive Solar Conference, Columbus, OH, September 23, 1984. American Solar Energy Society, Boulder, CO; (pp. 63-68) (1984, August)

Results of a parametric study of the energy performance of a prototypical single-family ranch-style house are presented. The DOE-2.1B computer program was used to analyze the variation in heating, cooling, and total energy requirements due to changes in the following fenestration characteristics: orientation, size, conductance, and shading coefficient. These parameters allow us to estimate the performance of hypothetical fenestration systems using advanced aperture materials as well as commercially available products. The work represents the initial phase of a study in which the influence of other residential parameters such as internal loads, infiltration levels, natural ventilation, use of night insulation, shade management, and overhangs will also be investigated. Climate sensitivity was established by considering results from Madison, Wisconsin, and Lake Charles, Louisiana. To simplify the analysis, multiple regression techniques were used to generate a simplified algebraic expression that relates energy use to the parameters varied. This representation could form the technical basis for simplified design tools for selecting optimal fenestration parameters.

515
Sexton, K., L.M. Webber, S.B. Hayward, and R.G. Sextro, California Department of Health Services, Berkeley, CA

Characterization of Particle Composition, Organic Vapor Constituents, and Mutagenicity of Indoor Air Pollutant Emissions

Environment International 12(1-4):351-362; Indoor Air Quality and Climate, Proceedings of the Third International Conference, Stockholm, Sweden, August 20, 1984 (1984)

A joint chamber experiment was carried out by the California Indoor Air Quality Program and Lawrence Berkeley Laboratory to characterize particle and organic vapor emissions from several important indoor sources, including a gas range, tobacco smoking, hamburger frying, a kerosene heater, and selected aerosol spray products. Among the emissions data collected for each source were particle size distributions, particle-phase chemical compositions, volatile organic compounds, and mutagenicity of particles and vapor-phase constituents. Findings were used to assess qualitatively the nature of airborne emissions from each source and to compare emission constituents among source categories. This approach is a necessary first step in evaluating the feasibility of developing unique signatures for individual sources using a broad array of emission characteristics.

516
Sextro, R.G., Lawrence Berkeley Laboratory, Berkeley, CA

Understanding the Origin of Radon Indoors: Building a Predictive Capability

LBL-20210; 22 pp.; CONF-8505195; Characterization of Sources of Indoor Air Contaminants, Proceedings of an EPA Conference, Chapel Hill, NC, May 12, 1985 (1985, December)

Indoor radon concentrations one to two orders of magnitude higher than the U.S. average of approximately 60 Bq/cu m (approximately 1.5 pCi/l) are not uncommon, and concentrations greater than 4000 Bq m(E-3) have been observed in houses in areas with no known artificially-enhanced radon sources. In general, source categories for indoor radon are well known: soil, domestic water, building materials, outdoor air, and natural gas. Soil is thought to be a major source of indoor radon, either through molecular diffusion (usually a minor component) or convective flow of soil gas. While soil gas flow into residences has been demonstrated, no detailed understanding of the important factors affecting the source strength of radon from soil has yet emerged. Preliminary work in this area has identified a number of likely issues, including the concentration of radium in the soil, the emanating fraction, soil type, soil moisture content, and other factors that would influence soil permeability and soil gas transport. Because a significant number of dwellings are expected to have indoor radon concentrations above guideline levels, a predictive capability is needed that would help identify geographical areas having the potential for high indoor concentrations. This paper reviews the preliminary work that has been done to identify important soil and building characteristics that influence the migration of radon and outlines the areas of further research necessary for development of a predictive method.

517
Sextro, R.G., J. Harrison, B.A. Moed, K.L.

Revzan, B.H. Turk, D.T. Grimsrud, A.V. Nero, D.C. Sanchez, and K.Y. Teichman, Lawrence Berkeley Laboratory, Berkeley, CA

Intensive Study of Radon and Remedial Measures in New Jersey Homes: Preliminary Results

LBL-23128; DOE/ER/60493-1 (Vol. 2); CONF-870853; Indoor Air '87, Indoor Air Quality and Climate - Volume 2: Environmental Tobacco Smoke, Multicomponent Studies, Radon, Sick Buildings, Odors and Irritants, Hyperreactivities and Allergies, B. Seifert, B., H. Esdorn, M. Fischer, H. Rueden, and J. Wegner, (eds.), Proceedings of the Fourth International Conference, Berlin, Federal Republic of Germany, August 17-21, 1987; (pp. 295-299) (1987)

In order to examine the influence of environmental and building factors on radon entry into homes, an intensive investigation of radon source characterization, entry mechanisms, procedures for remediation diagnosis, and mitigation system performance evaluation is being conducted in occupied New Jersey, USA, homes. One home serves as a control and remains in the original state during the experiment. Radon mitigation systems are installed in the other six homes. Indoor radon levels, indoor and outdoor temperatures, windspeed and direction, pressure differentials, soil temperature and moisture are some of the parameters being monitored continuously. Periodic measurements of soil air permeability, soil gas radon concentrations, ventilation rates, and radon progeny are also being conducted. The homes will be monitored for a 12 month period and various mitigation systems cycled on and off on a weekly basis. The relation of the various parameters to radon entry is discussed and implications for radon mitigation diagnostics are presented.

518
Sextro, R.G., et al., Lawrence Berkeley Laboratory, Berkeley, CA

Radon Entry and Control in Seven Homes with Basements

LBL-25292 (1988)

519
Sextro, R.G., B.A. Moed, W.W. Nazaroff, K.L. Revzan, A.V. Nero, and P.K. Hopke, Lawrence Berkeley Laboratory, Berkeley, CA

Investigations of Soil as a Source of Indoor Radon

LBL-21572; CONF-860425; HTD-Vol-76; Radon and Its Decay Products: Occurrence, Properties, and Health Effects, Proceedings of the 191st American Chemical Society National Meeting, New York, NY, April 13, 1986. American Chemical Society, Washington, DC, 1987; (pp. 10-29) (1987)

The predominant source of indoor radon in most single-family housing in the U.S. is the soil adjacent to the house substructure. The authors examined factors influencing the production and transport of radon in soil and into buildings. A number of important parameters have been identified and their effect on radon production and migration assessed, including radium concentration, moisture content, air permeability, and grain size distribution of soils. The potential regional variations in parameters affecting radon have been evaluated by examining geographic data, including surface radium concentrations and general soil data. We have also investigated factors influencing radon migration into individual dwellings. Coupling between the building shell and the surrounding soil has been demonstrated experimentally, and pressure-field mapping and soil permeability measurements have been carried out.

520
Sextro, R.G., A.V. Nero, and D.T. Grimsrud, Lawrence Berkeley Laboratory, Berkeley, CA

Indoor Air Quality: Sources and Control

AIP Conference Proceedings 135(1):229-246; CONF-850414; Proceedings of an American Physical Society General Meeting, Washington, DC, April 25, 1985 (1985, November 25)

The nature of the indoor air quality problem is described; methods of control or reduction of indoor radon and radon progeny concentrations have been reviewed. These techniques may be categorized as radon source reduction, radon removal, and radon progeny removal. There are a number of potential sources of radon in U.S. housing, including soil, potable water, and building materials. In most cases, it appears that flow of radon-bearing soil gas into houses, driven by a slight negative pressure differential across the building shell, is a major source of indoor radon; this pressure-driven flow appears to be the most likely source of radon that can account for the elevated radon concentrations observed in some houses. There are a number of radon source control techniques; their effectiveness will depend upon characteristics of the house substructure and the details of the specific application. While the results of such remedial measures have varied and the data base from which to generalize is small, five-to-ten-fold reductions in radon concentration have been reported.

521
Sextro, R.G., F.J. Offermann, W.W. Nazaroff, A.V. Nero, K.L. Revzan, and J. Yater, Lawrence Berkeley Laboratory, Berkeley, CA

Evaluation of Indoor Aerosol Control Devices and Their Effects on Radon Progeny Concentrations - Revision

LBL-17598 (Rev.); 22 pp.; CONF-840803; Indoor Air Quality and Climate, Proceedings of the Third International Conference, Stockholm, Sweden, August 20, 1984; Environment International 12:429-438 (1984, November)

Eleven portable air cleaning devices have been evaluated for control of indoor concentrations of respirable particles, and their concomitant effects on radon progeny concentrations have been investigated. The experiments were conducted in a room-size chamber using cigarette smoke and radon injection from an external source. Of the devices examined the electrostatic precipitators and extended surface filters had significant particle removal rates, while the particle removal rates for several small panel-filters, an ion-generator, and a pair of mixing fans were found to be essentially negligible. The evaluation of radon progeny control produced similar results; the air cleaners which were effective in removing particles were also effective in reducing radon progeny concentrations. At the low particle concentrations, deposition of the unattached radon progeny on room surfaces was found to be a significant removal mechanism. Deposition rates of attached and unattached progeny have been estimated from these data, and were used to calculate the equilibrium factors for total and unattached progeny concentrations as a function of particle concentration. While particle removal reduces total airborne radon progeny concentrations, the relative alpha decay dose to the lungs appears to change very little as the particle concentration decreases due to the greater radiological importance of unattached progeny.

522
Sharp, T.R.

Development of Monitoring Protocol for Commercial Buildings: Data Specification Issues

(1985, March)

523
Sharp, T.R., Oak Ridge National Laboratory, Oak Ridge, TN

Predicting Energy Use: Influence of the Recording Interval - Final Report

CONF-860818; Energy Efficiency in Buildings, Proceedings of the American Council for an Energy Efficient Economy Santa Cruz Summer Study, Santa Cruz, CA, August 17, 1986; (13 pp.) (1986, June)

This paper discusses a study that shows that the recording interval has considerable influence on the heating energy use rate (slope) and the base temperature resulting from a regression model using heat energy use. Fifteen-minute space heating energy use data recorded for four electrically-heated homes in Minneapolis, Minnesota area between January 1 and April 30, 1982 were used in this study.

524
Sharp, T.R., and J.M. MacDonald, Oak Ridge National Laboratory, Oak Ridge, TN

Estimating Balance Point Temperatures for Residential Buildings

ORNL/CON-209; 34 pp. (1987, August)

This report deals with the estimates of balance point temperatures from linear regression-based models used in predicting energy use in residential buildings. The balance point temperature of a building is defined as the long-term average outdoor temperatures below which the space-heating system must operate to maintain the desired indoor temperature. This balance point temperature is used in the comparison of energy use data recorded during different monitoring (i.e., climatic) periods, as in evaluating retrofits, or the comparison of buildings experiencing different weather conditions. The report also compares three methods for estimating balance point temperatures using both total (whole-house) and space-heating energy consumption data from seven homes. In addition, it discusses the use of linear regression models in modeling energy use and the behavior of these models and factors of influence and shows that the treatment of data in energy use regression models can have significant effects on balance point temperatures.

525
Sherman, M.H., Lawrence Berkeley Laboratory, Berkeley, CA

Estimation of Infiltration From Leakages and Climate Indicators

Energy and Buildings 10(1):81 (1987)

A simple model is developed for the estimation of annual infiltration rates in single-family houses using indicators for both house tightness (air changes at 50 Pa) and site climate (the leakage-infiltration ratio). A map of the leakage-infiltration ratio in the U.S. for the reference case is also included.

526
Sherman, M.H., Lawrence Berkeley Laboratory, Berkeley, CA

A Simplified Model of Thermal Comfort

LBL-15923; Energy and Buildings 8(1):37-50 (1985, February)

The purpose of conditioning the air in a building is to provide a safe and comfortable environment for its occupants. Satisfaction with the environment is composed of many components, the most important of which is thermal comfort. The principal environmental factors that affect human comfort are air temperature, mean radiant temperature, humidity, and air speed; virtually all heating, ventilating and air-conditioning (HVAC) systems, however, are usually controlled only by an air-temperature set-point. Significant efficiency improvements could be achieved if HVAC systems responded to comfort levels rather than air-temperature levels. The purpose of this report is to present a simplified model of thermal comfort based on the original work of Fanger, who related thermal comfort to total thermal stress on the body. The simplified solutions allow the calculation of predicted mean vote (PMV) and effective temperature which (in the comfort zone) are linear in the air temperature and mean radiant temperature, and quadratic in the dew point, and which can be calculated without any iteration. In addition to the mathematical expressions, graphical solutions are presented.

527
Sherman, M.H., Lawrence Berkeley Laboratory, Berkeley, CA

Description of ASHRAE's Proposed Air Tightness Standard

LBL-17585; 32 pp.; CONF-841049; The Implementation and Effectiveness of Air Infiltration Standards in Buildings, Proceedings of the Fifth AIC Conference, Reno, NV, October 1, 1984 (1986, March)

Because the load due to air infiltration typically accounts for one-third of space conditioning loads, ASHRAE (American Society of Heating, Refrigeration and Air-Conditioning Engineers) is in the process of writing a standard which addresses the maximum leakage associated with good construction. This standard, SPC 119P, is a link between ASHRAE Standard 90, which addresses energy conservation in new residential construction, and Standard 62, which specifies the minimum acceptable ventilation to achieve adequate indoor air quality. Within Standard 119 there is currently a classification scheme that groups building tightness into categories depending on envelope leakage, floor area and building height. In addition to being used for this residential leakage standard, this classification scheme is intended to be used to label the tightness of any building residential or commercial, new or existing. This report will present the background around SPC 119P, indicate a proposed form that the standard may take, and present some of the rationale behind it.

528
Sherman, M.H., Lawrence Berkeley Laboratory, Berkeley, CA

Infiltration Degree-Days: A Statistic for Quantifying Infiltration-Related Climate

LBL-19237; 25 pp.; CONF-8606125; Proceedings of the Annual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Portland, OR, June 22, 1986 (1986, April)

A new statistic, Infiltration Degree-Days (IDD), is introduced for quantifying the climatic conditions that influence infiltration. The well-known energy statistic, Degree Days (DD), is used to indicate the severity of climate relative to the conduction load through the building envelope (usually during the heating season). Infiltration Degree-Days (IDD) serves the same function for calculating infiltration and infiltration-related processes that standard degree-days has served for calculating conduction and conduction-related processes. Although standard degree-days is often used to estimate the entire load (i.e., conduction, radiation, and infiltration), it is calculated assuming a linear energy-flow relationship. IDD is designed to overcome the inaccuracies inherent in using standard degree-days for processed like infiltration that are nonlinear (in temperature and other climatic variables); they also potentially solve the problems associated with the use of degree-day formalisms for calculating cooling loads or any situations where the determination of latent heat is a problem. This report presents parallel derivations for standard and infiltration degree-days and includes formulas for determining the base temperature (and enthalpy) methods similar to the many variable-based degree-day methods currently in use for envelope-dominated structures. Also included are tables of heating and cooling IDD for various cases and selected cities in North America.

529
Sherman, M.H., Lawrence Berkeley Laboratory, Berkeley, CA

Multizone Modeling and Air Leakage Analysis

LBL-19776; 20 pp.; CONF-8509198; Proceedings of an AIC Conference, Het Meerdal, Netherlands, September 16, 1985 (1985, November)

Research on ventilation and infiltration has proliferated steadily over the last few years. Air leakage analysis and multicell modeling techniques have emerged as two of the most interesting topics in current infiltration-related basic research. This report reviews twelve significant papers concerned with multizone infiltration and air leakage presented at the ASHRAE conference.

530
Sherman, M.H., Lawrence Berkeley Laboratory, Berkeley, CA

Air Infiltration in Buildings

LBL-20120 (1985, August)

531
Sherman, M.H., Lawrence Berkeley Laboratory, Berkeley, CA

Exegesis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings

LBL-21040; 23 pp.; CONF-861221; Guidelines for Air Infiltration, Ventilation, and Moisture Transfer, Proceedings of the BTECC/DOE Symposium, Fort Worth, TX, December 2-4, 1986 (1986, July)

The American Society of Heating, Refrigerating and Air Conditioning Engineers has been actively developing consensus standards to govern recommended energy use in buildings. One of these standards is Standard 119, Air Leakage Performance for Detached Single-Family Residential Buildings. Authors present the derivation of the standard and an interpretation of its potential effects.

532
Sherman, M.H., Lawrence Berkeley Laboratory, Berkeley, CA

Analysis of Errors Associated with Passive Ventilation Measurement Techniques

LBL-23088 (1987)

533
Sherman, M.H., and J.B. Dickinson, Lawrence Berkeley Laboratory, Berkeley, CA

Fan Pressurization Techniques for the Estimation of Air Infiltration

LBL-19336 (1985, December)

534
Sherman, M.H., and M.P. Modera, Lawrence Berkeley Laboratory, Berkeley, CA

Low Frequency Measurement of the Leakage of Enclosures

LBL-20121 (1986, April)

535
Sherman, M.H., and M.P. Modera, Lawrence Berkeley Laboratory, Berkeley, CA

Signal Attenuation Due to Cavity Leakage

LBL-24289 (1988)

536
Sherman, M.H., R.F. Szydlowski, P.G. Cleary, M.P. Modera, and M.D. Levine, Lawrence Berkeley Laboratory, Berkeley, CA

Development and Implementation of Survey Techniques for Assessing In-Situ Appliance Efficiencies

LBL-23455; 97 pp. (1987, May)

A study was conducted to develop and field-test audit procedures that could be used in a large survey of in-situ appliance efficiency indicators. The appliances concerned were refrigerators, gas and electric water heaters, central air conditioners, and central gas furnaces. The efficiency indicators measured were compared to the manufacturer's rated values as determined by the California appliance standards procedures. The audit procedures field test involved 61 homes during summer 1986 and winter 1986-1987 and included actual in-situ appliance efficiency measurements using the same audit procedures that would have been used in a larger study. Appliances were submitted to one-day short-term efficiency tests and one-week long-term monitoring of energy use and operational characteristics. Based upon the results of this study, the audit procedures for a large survey would consist of one-day testing of the water heater, air conditioner, and furnace, and one-week monitoring of the refrigerator.

537
Sherman, M.H., and D.J. Wilson, Lawrence Berkeley Laboratory, Berkeley, CA

Relating Actual and Effective Ventilation in Determining Indoor Air Quality

LBL-20424; Building and Environment 21(3/4):135-144 (1986, September)

538
Sherman, M.H., and D.J. Wilson, Lawrence Berkeley Laboratory, Berkeley, CA

Ventilation Effectiveness and Distribution in Naturally Ventilated Buildings

LBL-21057 (1988)

539
Silver, J., and R.P. Tye, Oak Ridge National Laboratory, Oak Ridge, TN; Dynatech Scientific, Inc., Cambridge, MA

A Survey of Building Anomalies and Assessment of Thermal Break Materials for Anomaly Correction - Volume II: Proceedings

ORNL/Sub-83/70376/2; DYNATEC RPT-2312/2; Building Envelope Thermal Anomalies, Proceedings of a Department of Energy Workshop, Gaithersburg, MD, January 10-11, 1985 (1985, July)

540
Silver, J., R.P. Tye, and D.L. Brownell, Oak Ridge National Laboratory, Oak Ridge, TN; Dynatech Scientific, Inc., Cambridge, MA

A Survey of Building Anomalies and Assessment of Thermal Break Materials for Anomaly Correction

ORNL/Sub-83/70376/1; DYNATEC RPT-2312/1 (1985, July)

541
Siminovitch, M.J., F.M. Rubinstein, T.A. Clark, and R. Verderber, Lawrence Berkeley Laboratory, Berkeley, CA

Luminaire/Plenum/HVAC Simulator

LBL-19168; 8 pp.; CONF-851071; Proceedings of the Annual IEEE-Industry Applications Society Meeting, Toronto, Ontario, Canada, October 6, 1985 (1985, July)

This paper describes a new apparatus designed to model the physical parameters that affect fluorescent lamp performance under realistic operating conditions. These parameters include fixture type, mounting configuration, HVAC integration, and room air temperature, which directly determines the minimum lamp wall temperature (MLWT, and, therefore, the resulting light output of the lamp/ballast system. This apparatus is used principally to measure MLWT under operating conditions, which enables us to identify the effects the major parameters have on lamp/ballast system performance. Initial parametric results illustrate the use of this apparatus to provide representative MLWTs for a range of application conditions.

542
Siminovitch, M.J., F.M. Rubinstein, T.A. Clark, and R. Verderber, Lawrence Berkeley Laboratory, Berkeley, CA

Maintaining Optimum Fluorescent Lamp Performance Under Elevated Temperature Conditions

LBL-21004; 15 pp.; CONF-8608179; Proceedings of the 1986 Annual Illuminating Engineering Society Conference, Boston, MA, August 17-21, 1986 (1986, April)

This paper describes a new technique for optimizing fluorescent lamp performance under elevated temperature conditions. This approach uses a thermo-electric Peltier device to produce a localized cold spot temperature of approximately 40 deg C, allowing the lamps to maintain maximum light output and efficacy independent of prevaility ambient temperatures inside a luminaire. Experimental data showed that a 20% increase in light output and a 10% increase in efficacy over typically lamp performance in a warm fixture environment can be obtained using this device.

543
Smith, S.A., L.J. Davis, and B.A. Garrett, Pacific Northwest Laboratory, Richland, WA

Potential of the Tractor-Trailer and Container

Segments as Entry Markets for a Proposed Refrigeration Technology

PNL-5953; 69 pp. (1987, May)

In this report the refrigerated trailer and container segments of the transportation industry are evaluated as potential entry markets for a proposed absorption refrigeration technology. To perform this analysis the existing transportation refrigeration industry is characterized; this includes a description of the current refrigeration technology, rating systems, equipment manufacturers, maintenance requirements, and sales trends. This information indicates that the current transportation refrigeration industry is composed of two major competitors, Thermo King and Carrier. In addition, it has low profit potential, some barriers to entry and low growth potential. Data are also presented that characterize the transportation refrigeration consumers, specifically, major groups, market segmentation, consumer decision process, and buying criteria. This consumer information indicates that the majority of refrigerated trailer consumers are private carriers, and that the majority of refrigerated container consumers are shipping companies. Also, these consumers are primarily interested in buying reliable equipment at a low price, and are quite satisfied with existing refrigeration equipment.

544

Smith, S.A., and D.R. Johnson, Pacific Northwest Laboratory, Richland, WA

Identification and Evaluation of Data Sources for the Commercial Building Retrofit Market

PNL-6015; 31 pp. (1986, October)

The objectives of this study are to identify data sources that provide information on current and future levels of commercial buildings retrofit activity in the U.S., and to evaluate the coverage these data sources provide the commercial retrofit industry. Data sources evaluated include reports, magazines, computerized data bases, and surveys. Relevant data sources were identified through a literature review and by telephone and mail contacts with building industry experts and trade associations. A brief summary of each of the data sources is provided and recommendations are made for gathering additional data to supplement the existing data source.

545

Soderstrom, E.J., E.D. Copenhaver, M.A. Brown, and J.H. Sorensen, Oak Ridge National Laboratory, Oak Ridge, TN

Enhancing Technology Through Laboratory/Industry Cooperative Research and Development

ORNL-6107 (1985, March)

This report reviews various approaches that have been used to structure cooperative interactions between private industry and public institutions such as universities and federal laboratories in efforts to stimulate increased technological innovation and technology transfer. Section 1 provides background and an overview of past efforts to stimulate technology transfer from government-sponsored R&D to the private-sector. Section 2 reviews a variety of programs and approaches that have been initiated at different institutions to structure cooperative interactions with industry. Section 3 reviews the operation of various cooperative arrangements with industry practiced at Oak Ridge National Laboratory (ORNL), with particular attention on the laboratory's user facilities. Section 4 examines the factors influencing the success or failure of different types of cooperative arrangements. Finally, Section 5 provides several recommendations for means of enhancing ORNL's cooperative interactions with industry.

546

Sonderegger, R.C., P.G. Cleary, and J.B. Dickinson, Lawrence Berkeley Laboratory, Berkeley, CA; Morgan Systems Corporation, Berkeley, CA

Calculation of Variable-Base Degree-Days and Degree-Nights from Monthly Average Temperatures

LBL-18660; CONF-850606; Proceedings of the Semiannual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Honolulu, HI, June 23-26, 1985; ASHRAE Transactions 91(2B):875-892 (1985)

The Computerized Instrumented Residential Audit (CIRA), a micro-computer building energy analysis program developed at Lawrence Berkeley Laboratory, uses a monthly variable-base degree-day method to calculate heating and cooling loads. The method's unique feature is its ability to model thermostat setbacks and storage of solar gain. The program accomplishes this by dividing each day into two periods, "average day" (8 a.m. to 8 p.m.) and "average night" (8 p.m. to 8 a.m.), with different base temperatures. For each mode (heating or cooling) and for each period (day or night), the program reconstructs degree-days as a function of average monthly day or night temperature using three empirical coefficients specific to the location. A comparison is made between degree-days computed from hourly weather tapes and those predicted using this method. The root mean square error between predicted and actual degree days is typically between 3 and 12 degree-days per month. Tables of the coefficients are given for over 150 locations in the United States, computed from hourly dry-bulb temperatures on TRY and TMY tapes. Seasonal predictions of heating and cooling energy budgets using this method show good correspondence to the DOE-2 hourly simulation method.

547
Spiewak, I., and F.D. Boercker, Oak Ridge National Laboratory, Oak Ridge, TN

Commercial Building Energy Monitoring Survey

(1985, December)

548
Spitzglas M., M. Navvab, J.J. Kim, and S. Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

Scale Model Measurements for a Daylighting Photometric Database

LBL-17286; 30 pp.; EEB-W-85-09; CONF-8507101; Proceedings of the Annual Illuminating Engineering Society (IES) Technical Conference, Detroit, MI, July 21, 1985 (1985, March)

We present initial results of a study to produce a high-precision photometric reference data base using scale model photometry and computational daylighting prediction tools. For this study the SUPERLITE computer code was used. We illustrate the importance and difficulty of fine-tuning the scale model experimental set-up and measurement procedures to produce highly precise results. We discuss the advantage of separating the direct component of illumination from the internal reflected component as an aid to understanding discrepancies between measurements and calculations. We use results of the study to suggest the circumstances in which calculation procedures should be used to generate the references, and those in which the precise scale model photometry is the recommended technique. Further research directions in the field are described.

549
Sterling, R., G. Meixel, and L. Shen, University of Minnesota, Minneapolis, MN; Undercurrent Design Research, New Haven, CT; Massachusetts Institute of Technology, Cambridge, MA

Assessment of the Energy Savings Potential of Building Foundation Research

ORNL/Sub-84/00240/1 (1985, January)

550
Stoecker, W.F., Oak Ridge National Laboratory, Oak Ridge, TN

Condensing Heat Transfer with Nonazeotropic Refrigerant Mixtures

CONF-841231; Research and Development on Heat Pumps for Space Conditioning Applications, Proceedings of the DOE/ORNL Heat Pump Conference, Washington, DC, December 10, 1984 (1985, August)

551
Stoecker, W.F., and D.L. Boggs, Oak Ridge National Laboratory, Oak Ridge, TN

Single Train and Separating Cycles Using Refrigerant Mixtures

ORNL/Sub-81/7762/5&01 (1985, June)

552
Stovall, T.K., Oak Ridge National Laboratory, Oak Ridge, TN

Hood River Conservation Project: Load Analysis

ORNL/CON-240; 116 pp. (1987, November)

As the costs of energy and energy-producing facilities have risen during the last 15 years, many people have suggested that investments in conservation would show greater economic benefits that similar investments in power plants. The Hood River Conservation Project (HRCP) was designed to determine whether such a concept was feasible in the Northwest. This report evaluates the HRCP load, or capacity, savings, as opposed to overall energy savings. The data from 314 monitored homes form the cornerstone for this analysis. A three-phase feeder line was also monitored to assess the capacity savings on a primarily residential feeder.

553
Stovall, T.K., and L.C. Fuller, Oak Ridge National Laboratory, Oak Ridge, TN

Effect of Lifestyle on Energy Use Estimations and Predicted Savings

ORNL/CON-241; 45 pp. (1988, March)

Audit predictions of energy-conservation savings are usually much higher than the savings actually achieved. Speculation about possible causes for this discrepancy has often centered around residents' lifestyle, specifically their indoor temperature management. Detailed indoor temperature data and extensive demographic information were available for 300 homes in Hood River, Oregon. These data were analyzed to examine the effect of demographic variables on indoor temperature and energy use. Changes in indoor temperature before and after retrofit were also examined. The effects of these variables were very small. Some small improvements to auditing procedures can be suggested based on this analysis. However, the major conclusion is that while some takeback of energy savings is occurring, it is very small in magnitude and cannot explain the large differences between predicted and achieved energy savings.

554
Stovall, T.K., and M.A. Kuliasha, Oak Ridge National Laboratory, Oak Ridge, TN

An Analysis of Lifestyle Effects on Residential Energy Use

ORNL/CON-170; 56 pp. (1985, February)

An analysis of a large data set was performed to identify lifestyle trends or relationships that should be accounted for in retrofit performance research. Occupant-controlled thermostat settings, as reflected by indoor temperature or heating and air conditioning energy use, were examined with respect to outdoor temperature, heating system type, family size, house size, and house type. Hot-water energy use was similarly examined. Several trends associated with these variables were identified: homes with central thermostats are more likely to use nighttime temperature setback during the winter than those with individual room controllers; outdoor temperature has a stronger effect on thermostat management during the winter than during the summer; house type affects air conditioner energy use and may shift the winter/summer balance of savings for some retrofit measures; and hot water use varies seasonally, and the variation is most noticeable during the fall months.

555
Sullivan, R., D. Arasteh, G. Sweitzer, R. Johnson, and S. Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

The Influence of Glazing Selection on Commercial Building Energy Performance in Hot and Humid Climates

LBL-23287; 20 pp.; BS-247; CONF-8709245; Air Conditioning in Hot Climates, Proceedings of the ASHRAE Conference, Singaport, Malaysia, September 3-5, 1987 (1987, July)

This paper presents a comparative study in which commercial building perimeter zone electric energy (cooling, lighting, fan) and peak electric demand are analyzed as a function of window glazing type, with a particular emphasis on the use of glazings with wavelength-selective solar-optical properties. The DOE-2.1C energy analysis simulation program was used to generate a data base of the electric energy requirements of a prototypical office building module located in Singapore. Algebraic expressions derived by multiple regression techniques permitted a direct comparison of those parameters that characterize window performance in hot and humid climates: orientation, size, and solar-optical properties. Also investigated were the effects of exterior and interior shading devices, as well as interior illuminance level, power density, and lighting controls to permit the use of daylighting. These regression equations were used to compare the energy implications of conventional window designs and newer designs in which the type of coating and substrate were varied. The analysis shows the potential for substantial savings through combined solar load control and lighting energy use reduction with daylighting.

556
Sullivan, R., Y.J. Huang, J. Bull, I. Turiel, R.L. Ritschard, and S. Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

Thermal Analysis of Buildings: Configuration Perturbations and Observed Climate Interface

LBL-19383; 25 pp.; CONF-860106; Proceedings of the Semiannual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, San Francisco, CA, January 19, 1986 (1986, April)

Results are presented that indicate a proportional relationship between building thermal loads for varying configuration parameters. Through the use of numerous building energy simulations using both the DOE-2.1 and BLAST energy analysis computer programs, it is shown that the relationship is independent of climatic location and covers a broad spectrum of those variables that influence a building's energy use. The theoretical justification associated with such a phenomenon is treated using a multiple regression-derived algebraic expression that clearly establishes the linear independence of a building's heat gain/loss components. Procedures are defined for the simplification of future parametric studies of the thermal analysis of buildings using a methodology that incorporates the observations reported herein.

557
Sullivan, R., and S. Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

Residential Window Performance Analysis Using Regression Procedures

LBL-19245 (Rev.); 9 pp.; CONF-850817; Building Energy Simulation, Proceedings of a Conference, Seattle, WA, August 21, 1985 (1985, July)

The development of a simplified algebraic expression that can be used to predict the effects of various window parameters on residential energy use is documented. A comprehensive parametric study of a prototypical single-family ranch-style house was performed using the DOE-2.1B energy analysis simulation program. The data base generated for the study consisted of the heating, cooling, and total energy requirements and subsequent costs due to changes in the fenestration characteristics of orientation, size, conductance, and shading coefficient. Incremental effects due to shade management, night insulation, and overhangs were also part of the data base.

558
Sullivan, R., and S. Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

Window Performance Analysis in a Single-Family Residence

LBL-20079; 22 pp.; EEB-W-85-14;

CONF-851202; Thermal Performance of the Exterior Envelopes of Buildings - III, Proceedings of the DOE-ORNL-ASHRAE-BTECC Conference, Clearwater Beach, FL, December 2, 1985, 1421 pp. (1985, October)

This paper presents the results of a parametric study of fenestration in a single-family residential prototype. The DOE-2.1B energy analysis program was used to analyze the variation in heating and cooling energy requirements and resultant costs due to changes in the following fenestration characteristics: orientation, size, conductance, and shading coefficient. Incremental energy use changes due to the effects of night insulation, shade management, and overhangs were also examined. Sensitivity to climate was established by considering results from four distinct climatic zones representative of warm and humid (Lake Charles, LA), hot and dry (Phoenix, AZ), temperate (Washington, DC), and cold (Madison, WI) conditions. Analysis of the effects of hypothetical fenestration systems on building energy use was made possible by development of an algebraic expression through the use of multiple regression procedures. Such techniques also permitted the definition and isolation of those window characteristics that minimize residential energy use and/or cost.

559
Sullivan, R., and S. Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

Residential Heating and Cooling Energy Cost Implications Associated with Window Type

LBL-21578; 19 pp.; CONF-870101; Proceedings of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers Meeting, New York, NY, January 18-21, 1987; ASHRAE Transactions 93(1):1553 (1986, November)

A comparative study in which residential heating and cooling energy costs are analyzed as a function of window glazing type, with a particular emphasis on the performance of windows having low-emittance coatings are presented. The DOE-2.1B energy analysis simulation program was used to generate a data base of the heating and cooling energy requirements of a prototypical single-family ranch-style house. Algebraic expressions derived by multiple regression techniques permitted a direct comparison of those parameters that characterize window performance: orientation, size, conductance, and solar transmission properties. These equations are used to discuss the energy implications of conventional double- and triple-pane window designs and newer designs in which number and type of substrate, low-emittance coating type and location and gas fill are varied. Results are presented for the heating-dominated climate of Madison, WI, and cooling-dominated locations of Lake Charles, LA, and Phoenix, AZ. The analysis shows the potential for substantial savings but suggests that both heating and cooling energy should be examined when evaluating the performance of different fenestration systems.

560
Sweitzer, G., D. Arasteh, and S. Selkowitz, Lawrence Berkeley Laboratory, Berkeley, CA

Effects of Low-Emissivity Glazings on Energy Use Patterns in Nonresidential Daylighted Buildings

LBL-21577; 16 pp.; CONF-870101; Proceedings of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers Meeting, New York, NY, January 18-21, 1987; ASHRAE Transactions 93(1):1553 (1986, December)

Fenestration is the most significant envelope design determinant of energy use in nonresidential buildings. This paper presents an assessment of energy use effects of low-emissivity (low-E) versus conventional glazings for a range of window-to-wall ratios in a daylighted office building, in representative hot and cold climates. Low-E glazings transmit "cooler" daylight than their conventional counterparts because, for a given visible transmittance, they reflect a much larger fraction of incident solar infrared radiation. We thus use the ratio of visible transmittance to shading coefficient, which we define as K, to compare the effect of representative glazing characteristics on component and total-building energy use, peak electrical demand, and required cooling equipment sizes. Authors conclude that insulated glazings with low-E coatings can provide lighting and cooling energy savings in both hot and cold climates.

561
Szydlowski, R.F., Lawrence Berkeley Laboratory, Berkeley, CA

Energy Signature Monitor (ESM) - A Low Cost Class B Data Acquisition System

LBL-18725; 13 pp.; CONF-850241; Microcomputer Applications for Conservation and Renewable Energy, Proceedings of the First National Conference, Tucson, AZ, February 26, 1985 (1986, May)

The Lawrence Berkeley Laboratory has developed the Energy Signature Monitor (ESM), an innovative data acquisition system which addresses the data acquisition and analysis requirements of test programs which involve monitoring of large samples of buildings. Information about the typical number of sensors and the accuracy requirements for such large monitoring projects was incorporated into the development of the ESM in order to meet the needs of most researchers without adding unnecessary and expensive features. The ESM hardware includes a microprocessor-controlled data acquisition program, 16 analog channels, two pulse-count channels, a RS232 computer interface, and a removable EPROM-based data storage module. In conjunction with the hardware a complete data management software package, written to operate on a personal computer, was developed to facilitate analysis of the recorded data. A total of 23 ESMs have been built to-date, all of which are being used in a field monitoring study currently being conducted by Lawrence Berkeley Laboratory. Technical support is being provided to two private-sector companies that are interested in marketing a commercial version of the ESM.

562
Szydlowski, R.F., and P.G. Cleary, Lawrence Berkeley Laboratory, Berkeley, CA

In-Situ Measurements on Domestic Water Heaters

LBL-23543 (1988)

563
Szydlowski, R.F., and P.G. Cleary, Lawrence Berkeley Laboratory, Berkeley, CA

In-Situ Appliance Efficiency Audit Procedures

LBL-23582; CONF-880128; Proceedings of the 1988 American Society of Heating, Refrigerating and Air-Conditioning Engineers Winter Meeting, Dallas, TX, January 30, 1988. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA; ASHRAE Transactions 94(1):1007-1023 (1988)

A study was conducted to develop and field-test audit procedures that could be used in a large survey of in-situ appliance efficiencies. The appliances concerned were refrigerators, gas and electric water heaters, central air conditioners, and central gas furnaces. The efficiency indicators measured were compared too the manufacturers' rated values as determined by the California appliance standards procedures. The audit procedures field test involved 61 homes during summer 1986 and winter 1986-1987. Appliances were submitted to one-day short-term efficiency tests and one-week long-term monitoring of energy use and operational characteristics. The audit procedures were successful for refrigerators, the recovery efficiency of water heaters, and central gas furnaces. Water heater standby loss and air conditioner efficiency audit procedures are not practical at this time. An examination of alternative air conditioner audit procedures is advisable, whereas development of a practical audit procedure for measuring water heater standby loss is very unlikely. The successful audit procedures represent useful diagnostic tools that can be used in conjunction with all types of appliance end-use monitoring.

564
Teagan, W.P., Arthur D. Little, Inc., Cambridge, MA; Oak Ridge National

Laboratory, Oak Ridge, TN

Assessment of Free-Piston Stirling Engines as Heat Pump Drives

CONF-841231; Research and Development on Heat Pumps for Space Conditioning Applications, Proceedings of the DOE/ORNL Heat Pump Conference, Washington, DC, December 10, 1984; (pp. 195-205) (1985, August)

ORNL and the DOE have been supporting the development of FPSE/Heat Pump systems for over six years. These programs have contributed to advancing the state of knowledge on this technology on which to base future R&D and commercial development programs. The initial results of a program to assess the status and technology issues of FPSE/Heat Pump technology, formulate approaches for resolving technical problems which have arisen, and identify program planning options which will effectively use financial resources to undertake needed R and D leading to the development of systems with commercial potential are presented.

565
Teotia, A.P.S., and D.A. Poyer, Argonne National Laboratory, Argonne, IL

Macroeconomic Effects Under the Proposed District Heating and Cooling Tax Incentives Act of 1982

ANL-CNSV-TM-155 (1985)

In its energy conservation programs, the U.S. Department of Energy (DOE) has supported research into and development of district heating and cooling systems to meet energy demands in the residential and commercial sectors. Toward this goal, DOE requested Argonne National Laboratory to estimate the macroeconomic effects of the Senate bill known as the "District Heating and Cooling Tax Incentives Act of 1982." The first step was to estimate market penetration of district heating and cooling cogeneration energy systems under the provisions of the proposed act, using Argonne's district heating and cooling market penetration model. This model provided annual estimates of district heating and cooling investment and energy savings. In the second step, macroeconomic effects of district heating and cooling under the act's provisions were estimated using the annual model of the U.S. economy developed by Data Resources, Inc.

566
Ternes, M.P., Oak Ridge National Laboratory, Oak Ridge, TN

Single-Family Building Retrofit Performance Monitoring Protocol: Data Specification Guideline

ORNL/CON-196; 112 pp. (1987, June)

A data specification guideline was developed for use in the U.S. Department of Energy's (DOE's) Single-Family Building Energy Retrofit Research Program. A great deal has been learned regarding retrofit performance during the past decade through the analysis of monthly billing data collected on a large number of homes and from the analysis of more detailed data collected from a sample of homes. However, retrofit performance data collected from a significant sample of occupied homes and in more detail than billing data are required to address many research questions that remain unanswered. This guideline identifies the important data parameters that should be collected in research projects conducted by DOE and the private sector to address retrofit energy performance questions. Both one-time and time-sequential data parameters are identified and sufficiently defined to ensure that they are consistent and comparable between experiments. A minimum data set is identified, which must be collected in all experiments if the guideline is to be followed, in order that the observed energy savings can be normalized for outdoor temperature, indoor temperature, and internal load. Optional data parameters and data collection frequencies that can be collected to address additional research questions are also identified. These questions deal with the affects of occupant behavior, microclimate, and the distribution system on retrofit energy performance.

567
Thomas, J.R., Virginia Polytechnic Institute and State University, Blacksburg, VA

Calculational Model Development for Fibrous Thermal Insulation Transient Test Procedures

ORNL/Sub-85/27494/1; 68 pp. (1988, February)

A new theoretical model of transient combined radiation and conduction heat transfer in fibrous insulations has been developed and tested by comparison to experimental data obtained with the ORNL flat screen tester. This model predicts results which agree with this data to within plus or minus 1.2 degree C for all of the transient test results available. Sensitivities of the model to the pertinent radiative transfer properties of the insulation have been determined, and are presented in this report. The most important findings are: (1) the extinction coefficient of SRM 1451 fiberglass insulation is approximately 650 mp minus 1; and (2) the fiberglass used in the tests almost certainly contained sufficient moisture to significantly affect the test results.

568
Tong, T.W., University of Kentucky, Lexington, KY

Analysis of Transient Behavior and Radiation Measurements of Commercial Thermal Insulation

ORNL/Sub-83/43366/1; 65 pp. (1985, August)

This investigation was conducted to establish the effect thermal radiation had on the thermal response of porous insulating materials subjected to a transient experiment. The transient experiment was that employed to measure the thermal properties of thermal insulation using the flat screen tester at the Oak Ridge National Laboratory. Two combined radiative and conductive heat transfer models were considered. In one model, radiation was treated as a two-flux phenomenon and in the other, radiation was considered as a diffusive process. The results obtained from using the two-flux model indicated appreciable radiative effect on the overall heat transfer process. Comparisons between actual temperature-time data and predicted results obtained from the diffusive model were made. The comparisons showed that the predicted results agreed better with the experimental data when radiation was accounted for in the analysis. In conjunction with the heat transfer modeling, a radiation transmission experiment was conducted to measure the radiation properties of the NBS SRM 1450b and the NBS CTS porous thermal insulations. The radiation properties measured were: the extinction coefficient, the single scattering albedo, and the back-scattered fraction factor. These properties were reported as a function of temperature and radiation wavelength.

569
Tong, T.W., Oak Ridge National Laboratory, Oak Ridge, TN

Transient Heat Transfer Analysis and Radiative Properties Measurements of Porous Thermal Insulation

ORNL/Sub-83/43366/2 (1986, May)

A combined radiative and conductive heat transfer model that uses the two-flux equations for radiation exchange has been applied to analyze the transient heat transfer data obtained with the flat-screen tester at the Oak Ridge National Laboratory. The data included those for the National Bureau of Standards (NBS) transfer standard and the NBS 1450b fiberglass board. Predictions that deviated by no more than 0.2 deg C of the measured screen temperature rise were obtained. The results indicate that the model can be used in conjunction with the transient data to determine the thermophysical properties of porous insulations.

570
Tonn, B.E., and D.L. White, Oak Ridge National Laboratory, Oak Ridge, TN

Patterns of Residential Wood and Electricity Use: Results from the Hood River Conservation Project

Energy 13(6):485 (1988)

Significantly different daily patterns of wood and electricity use among 100 houses that contained both wood heat output and electricity use submeters installed as part of the Hood River Conservation Project, were identified. Authors found that patterns include low wood/high electricity, high wood/low electricity, and low wood/low electricity profiles. Profiles are not differentiable by day of week, but differ widely as outdoor temperatures drop. Houses that are small in size tend to use high electricity/low wood patterns whereas low electricity/high wood patterns are utilized by larger households and houses.

571
Tonn, B.E., D.L. White, and C. Carrier, Oak Ridge National Laboratory, Oak Ridge, TN

Energy Savings Due to Model Conservation Standards in Multifamily Buildings

CONF-880814-3; Energy Efficiency in Buildings, Proceedings of a Summer Study, Pacific Grove, CA, August 28-September 3, 1988; (14 pp.) (1988)

In the past several years, the Bonneville Power Administration and utilities in the U.S. Pacific Northwest have invested significant amounts of money in retrofitting existing buildings. This paper evaluates energy savings attributable to The Model Conservation Standards (MCS) in the unfamiliar sector. Forty-seven buildings with a total of 602 units comprise the MCS sample. Occupants of the building were surveyed about energy use, demographic characteristics, and characteristics of their apartment units. Differences in electricity use between the MCS and non-MCS samples and estimate differences in multifamily household electricity use were presented.

572
Traynor, G.W., Lawrence Berkeley Laboratory, Berkeley, CA

Field Monitoring Design Considerations for Assessing Indoor Exposures to Combustion Pollutants

LBL-19844; CONF-8505194; Characterization of Contaminant Emissions from Indoor Sources, Proceedings of a Conference, Triangle Research Park, NC, May 13, 1985; Atmospheric Environment 21(2):377-383 (1987)

Laboratory and controlled field studies of indoor air quality (IAQ) have characterized pollutant emission rates from combustion sources and have measured other key indoor air pollution parameters such as air exchange rates and indoor reactivity rates for the houses investigated. In addition, several field studies have attempted to measure, with varying degrees of success, pollutant exposures, indoor pollutant concentrations, and other parameters in large populations. To date, there exists no comprehensive strategy for assessing distributions of exposures in large populations. This paper outlines important parameters that affect combustion-related indoor air pollution concentrations and exposures, delineates weaknesses in our current understanding of exposures and field sampling methodologies, and mentions important considerations in planning appropriate field sampling strategies.

573
Traynor, G.W., Lawrence Berkeley Laboratory, Berkeley, CA

Selected Protocols for Conducting Field Surveys of Residential Indoor Air Pollution Due to Combustion-Related Sources

LBL-24487; 25 pp.; CONF-8704219; Design and Protocol for Monitoring Indoor Air Quality, Proceedings of the ASTM Symposium, Cincinnati, OH, April 26-29, 1987 (1987, October)

As buildings are tightened for energy conservation purposes, the concentration of indoor-generated air pollutants can increase. Federal agencies, state agencies, utilities, and public health organizations have an interest in indoor air-pollution levels and the impact various policy decisions will have on them. This paper identifies key parameters that affect indoor air pollutant levels from combustion-related sources and suggests protocols for measuring each parameter. Indoor air quality field studies should measure the indoor pollutant levels themselves and the key parameters that affect such levels. Key parameters such as appliance usage patterns, indoor pollutant reactivity rates, local ventilation effects, air exchange rates, and source usage driving forces are addressed. In addition, state-of-the-art measurement techniques, time sampling periods, and overall sample sizes needed are briefly discussed.

574

Traynor, G.W., J.R. Allen, M.G. Apte, J.R. Girman, and C.D. Hollowell, Lawrence Berkeley Laboratory, Berkeley, CA

Pollutant Emissions from Portable Kerosene-Fired Space Heaters

LBL-14301; Environmental Science and Technology 19:200 (1985)

575

Traynor, G.W., M.G. Apte, A.R. Carruthers, J.F. Dillworth, D.T. Grimsrud, and L.A. Gundel, Lawrence Berkeley Laboratory, Berkeley, CA

Indoor Air Pollution Due to Emissions From Wood-Burning Stoves

LBL-17854; 10 pp.; CONF-840612; Proceedings the Annual Air Pollution Control Association Meeting, San Francisco, CA, June 25, 1984, Vol. 2 (1985, April)

Wood-burning stoves have been found under some conditions to contribute to indoor concentrations of carbon monoxide, nitric oxide, nitrogen dioxide, and suspended particles, including benzo-A-pyrene. Indoor pollutant emissions from wood-burning stoves can be emitted into the indoor environment during starting, stoking, and reloading operations, or they can be emitted continuously if a leak or crack exists in the stove or its vent system. In this study the authors investigate the impact on indoor air quality from the use of four different wood-burning stoves in an occupied house under simulated use conditions. Measurements of carbon monoxide (CO), nitric oxide, nitrogen dioxide, formaldehyde, total suspended particles, submicron suspended particles and five polynuclear aromatic hydrocarbons (PAH) are discussed in this paper. The PAH compounds investigated were benzo(B)fluoranthene, benzo(k)fluoranthene, benzo(A)pyrene, benzo(GHI)perylene,andindeno(1,2,3-CD)pyrene.

576

Traynor, G.W., M.G. Apte, A.R. Carruthers, J.F. Dillworth, D.T. Grimsrud, and W.T. Thompson, Lawrence Berkeley Laboratory, Berkeley, CA

Indoor Air Pollution and Inter-Room Pollutant Transport Due to Unvented Kerosene-Fired Space Heaters

LBL-17600 (Rev.); Environment International 13:159-166 (1987)

Two kerosene-fired space heaters, one white-flame convective and one blue-flame radiant, were operated in the master bedroom of an unoccupied house under several simulated use conditions. Tests were conducted with the bedroom door and outside window closed, with the door closed and the window open 2.5 cm, with the door open 2.5 cm and the window closed, and with the door wide open and the window closed. The heaters were operated until an 8 C temperature rise was achieved in the room. Increases in bedroom concentrations of CO, CO2, NO, NO2, and O2 are reported. The increases in CO2 levels ranged from 2440 to 5440 ppm while the increases in NO2 levels ranged from 0.12 to 0.60 ppm. In addition, inter-room pollutant transport rates are reported for tests conducted with the window closed. While inter-room pollutant transport rates were less than 10 cu m/hr with the bedroom door closed, they were 30 plus or minus 10 cu m/hr with the bedroom door open 2.5 cm, and ranged from 190 cu m/hr to 3400 cu m/hr with the door fully open (74 cm).

577

Traynor, G.W., M.G. Apte, A.R. Carruthers, J.F. Dillworth, R.J. Prill, D.T. Grimsrud, and B.H. Turk, Lawrence Berkeley Laboratory, Berkeley, CA

Effects of Infiltration and Insulation on the Source Strengths and Indoor Air Pollution From Combustion Space Heating Appliances

LBL-22061; Journal of the Air Pollution Control Association 38(8):1011-1015 (1988, August)

Many energy conservation strategies for residences involve reducing house air exchange rates. Reducing the air exchange rate of a house can cause an increase in pollutant levels if there is an indoor pollution source and if the indoor pollutant source strength remains constant. However, if the indoor pollutant source strength can also be reduced, then it is possible to maintain or even improve indoor air quality. Increasing the insulation level of a house is a means of achieving energy conservation goals and, in addition, can reduce the need for space heating and thereby reduce the pollutant source strengths of combustion space heaters such as unvented kerosene space heaters, unvented gas space heaters, and wood stoves. In this paper, the indoor air quality trade-off between reduced infiltration and increased insulation in residences is investigated from combustion space heaters. Two similar residences were used for the experiment. One residence was used as a control and the other residence had infiltration and insulation levels modified. An unvented propane space heater was used as the source in this study. A model was developed to describe the dependence of both indoor air pollution levels and the appliance source strengths on house air exchange rates and house insulation levels.

578
Traynor, G.W., M.G. Apte, H.A. Sokol, J.C. Chuang, and J.L. Mumford, Lawrence Berkeley Laboratory, Berkeley, CA; Battelle Columbus Laboratories, Columbus, OH; U.S. Environmental Protection Agency, Research Triangle Park, NC

Selected Organic Pollutant Emissions from Unvented Kerosene Heaters

LBL-21355; 22 pp.; CONF-860606; Proceedings of the Air Pollution Control Association Annual Meeting and Exhibition, Minneapolis, MN, June 22, 1986 (1986, March)

This study has confirmed the results of other studies, i.e., that the kerosene combustion process can emit PAHs and nitrated-PAHs. In addition, kerosene heaters were found to emit many other organic compounds, including aliphatic hydrocarbons, alcohols, and ketones; phthalates; alkyl benzenes; and pentachlorophenol. Additional analysis is needed to correlate these results with health-effects data to determine the risk associated with these organic emissions. PAH and nitrated-PAH emissions are sufficiently important to justify additional quantitative studies; furthermore, examinations of other organic compounds of toxicological significance and of unvented combustion sources should be expanded. One very important observation of this study was that some estimates of the indoor reactivity of SVOCs were higher than 2/hr. This implies that reactivity rates for some SVOCs are more important than ventilation rates for determining indoor concentrations. Clearly, this indicates that future studies must quantify the indoor reactivity process for individual SVOCs in order to gain insight into potential indoor exposures to these compounds.

579
Traynor, G.W., et al., Lawrence Berkeley Laboratory, Berkeley, CA

Comparison of the "Hood" and "Chamber" Techniques for Quantifying Pollutant Emission Rates from Unvented Combustion Appliances and an Evaluation of Selected Organic Pollutant Emissions from Unvented Kerosene Heaters

LBL-22896 (1987, November)

580
Troyer, R., Manville Service Corporation, Denver, CO

High Temperature Calorimeter Performance Variable Study

ORNL/Sub-84/19712/1; 96 pp. (1986, April)

Oak Ridge National Laboratory with funding supplied by the Department of Energy sponsored the evaluation of a water calorimeter for thermal transmission testing of refractory fiber insulation using a ruggedness test. The specimens tested were low density refractory fiber flexible blanket insulation. The factors evaluated included: (1) emissivity of copper plate; (2) calorimeter to guard balance; (3) calorimeter to room temperature balance; (4) calorimeter water flow rate; (5) perimeter insulation; (6) type of hot side thermocouple; and (7) type of cold side thermocouple. A ruggedness test is a statistical method of evaluating step changes making multiple changes each test. Five of the seven factors were found to be significant at a minimum of one temperature. One plate versus three plates, two inch thick specimen versus three inch thick specimen and a release agent were three factors that were tested independently of the ruggedness test. The specimens were also tested in a guarded hot plate for comparison purposes. Recommendations are given to improve the design and operation of the calorimeter.

581
Tschanz, J.F., Argonne National Laboratory, Argonne, IL

Evaluating Options for Community Energy Plans: A Community Comparison

ANL-CNSV-TM-154 (1985)

In October 1978, under the auspices of the Comprehensive Community Energy Management Program (CCEMP), 17 communities of wide-ranging size began to develop local action plans for energy management. The program was sponsored by the Community Systems Branch of the U.S. Department of Energy (DOE) and was managed by Argonne National Laboratory (ANL). This report summarizes first the selection of options then the estimation of their energy, economic, employment, environmental, and utility impacts. Following, is a review of the methods used to compare the options and determine priorities among them. The materials used for this summary report are primarily the project documents from the communities. Emphasis in the report is placed on the methods used to estimate the impacts of proposed energy management options. However, emphasis is not on method as a cookbook sequence of numerical manipulations.

582
Tschanz, J.F., Argonne National Laboratory, Argonne, IL

Evaluating Potential Employment Effects of Community Energy Programs

CONF-8508111; Energy Conservation Program Evaluation: Practical Methods, Useful Results - Volume 1, Sessions 1-11, Proceedings of the Second National Conference, Chicago, IL, August 19, 1985; (pp. 233-249) (1985)

Through conservation and the use of locally available resources, an energy management program would reduce the drain on the local economy because of imported fuels and would benefit from the dollars retained locally in increased economic activity and employment. This paper examines the estimates, made by five communities during energy planning projects, of dollars retained locally and potential employment effects. Each community included a variety of energy management options within its project, ranging from simple, inexpensive retrofit improvements in individual structures to technologically sophisticated community energy supply systems. Comparisons of the aggregate results show wide variations among the five communities. Some of these differences may be real and attributable to specific differences in local conditions and proposed programs. Other differences, however, arise from the various methods and assumptions used by the communities in making their calculations. This paper interprets the results of these community evaluations by comparing the methods and assumptions they applied.

583
Turiel, I., Lawrence Berkeley Laboratory, Berkeley, CA

Energy Conservation Measures for Residential

Water Heaters

(1986)

584
Turiel, I., P. Albrand, Y.J. Huang, R.L. Ritschard, and D.J. Wilson, Lawrence Berkeley Laboratory, Berkeley, CA

Parametric Analysis of Impact of Reflective Glazing and Movable Window Insulation on Heating and Cooling Loads and Space Conditioning Costs in Residential Buildings

LBL-20217; 29 pp.; CONF-851202; Thermal Performance of the Exterior Envelopes of Buildings - III, Proceedings of the DOE-ORNL-ASHRAE-BTECC Conference, Clearwater Beach, FL, December 2, 1985, 1421 pp. (1986, January)

We studied the impact of reflective glazing and movable window insulation on heating and cooling loads in single-family and multifamily buildings for many U.S. locations. Regressions between loads and appropriate climatic variables allowed extension of our results to other climates where computer simulations were not performed but where climatic data are available. We calculated space conditioning fuel cost for each location studied and plotted the fuel cost savings for reflective glazing on a map of the United States. This procedure allows easy determination of the cost-effectiveness of these conservation measures in various climatic regions. For warm climates with large cooling loads and small or moderate heating loads, reflective glazing produces a substantial decrease in space conditioning cost (assuming gas heating and electric cooling). We found the use of movable insulation over windows to be economically justified in cold climates with electric heating.

585
Turk, B.H., J.T. Brown, K.L. Geisling-Sobotka, D.A. Froehlich, D.T. Grimsrud, J. Harrison, and K.L. Revzan, Lawrence Berkeley Laboratory, Berkeley, CA

Indoor Air Quality Measurements in 38 Pacific Northwest Commercial Buildings

LBL-21453; 26 pp.; CONF-860606; Proceedings of the Air Pollution Control Association Annual Meeting and Exhibition, Minneapolis, MN, June 22, 1986 (1986, June)

A Bonneville Power Administration-funded study monitored ventilation rates and a variety of indoor air pollutants in 38 Pacific Northwest commercial buildings. The buildings ranged in age from 6 months to 90 years, in size from 864 to 34,280 sq m, and occupancy from 25 to 2500 people. Building average formaldehyde (HCHO) concentrations were below the 20 ppb detection limit in 48% of the buildings. Nitrogen dioxide (NO2) concentration averages ranged from 5 ppb to 43 ppb and were lower than outdoor concentrations in 8 of 13 buildings. At only one site, an elementary school classroom, did carbon dioxide (CO2) exceed 1000 ppm. Radon (Rn) levels were elevated in one building with an average concentration of 7.4 pCi/l. Respirable particles (RSP) concentrations in smoking areas in 32 buildings had a geometric mean of 44 um g/cu m and ranged up to 308 um g/cu m at one site. In non-smoking areas the geometric mean RSP was 15 um g m(E-3). Outside air ventilation rates did not appear to be the single dominant parameter in determining indoor pollutant concentrations. Measured pollutant concentrations in 2 "complaint" buildings were below accepted guidelines. The cause of the complaints was not identified.

586
Turk, B.H., D.T. Grimsrud, J.T. Brown, K.L. Geisling-Sobotka, J. Harrison, and R.J. Prill, Lawrence Berkeley Laboratory, Berkeley, CA

Commercial Building Ventilation Rates and Particle Concentrations

LBL-23135; DOE/ER/60493-1 (Vol. 1); CONF-870853; Indoor Air '87, Indoor Air Quality and Climate - Volume 1: Volatile Organic Compounds, Combustion Gases, Particles and Fibres, Microbiological Agents, B. Seifert, B., H. Esdorn, M. Fischer, H. Rueden, and J. Wegner, (eds.), Proceedings of the Fourth International Conference, Berlin, Federal Republic of Germany, August 17-21, 1987; (pp. 610-614) (1987)

Ventilation rates have been measured in 38 commercial buildings that represent a variety of use types, sizes, ages, and mechanical system configurations. A single tracer (SF6) test was conducted once at 36 buildings over a two to four hour period based on mechanical system operation for a prior two-week period. Two buildings were tested a second time under different environmental conditions. Whole building ventilation rates ranged from 0.3 AcH to 4.2 AcH for the 40 building measurements with an average value of 1.5 AcH. Several pollutants were also monitored in the buildings for 10-day periods during working hours. Respirable suspended particles was the pollutant group that most frequently approached or exceeded elevated levels and was usually associated with local tobacco smoking.

587

Turk, B.H., D.T. Grimsrud, J. Harrison, and R.J. Prill, Bonneville Power Administration, Portland, OR; Lawrence Berkeley Laboratory, Berkeley, CA

A Comparison of Indoor Air Quality in Conventional and Model Conservation Standard New Homes in the Pacific Northwest: Final Report

DOE/BP/12921-1; 59 pp. (1988, October)

Ventilation and indoor air quality measurements have been made in 61 new houses located in two regions of the Pacific Northwest. Twenty-nine houses built to Model Conservation Standards (MCS) were compared to 32 Control houses, i.e., new houses built using conventional practices in the region. The MCS houses met the objective of having significantly reduced air leakage area. Yet their total ventilation rate (infiltration plus mechanical ventilation supplied by air-to-air heat exchangers) was the same as the infiltration rate observed in the sample of Control houses. These ventilation rates in both samples were about 0.3 AcH. Indoor pollutant concentrations were observed to be only poorly correlated with ventilation rates, an indication that other variables including pollutant source strengths and occupancy effects may be important. Pollutant measurements made in both samples revealed that 11% of the houses exceeded the BPA mitigation action level of 5 pCi/l for radon concentrations, while 16% exceeded the EPA guideline of 4 pCi/l. Thirty percent of the total houses exceed the 100 ppb formaldehyde guideline adopted by many organizations. Indoor pollutant concentrations were seen to vary more between geographic regions than between the two types of house construction.

588

Turk, B.H., D.T. Grimsrud, J. Harrison, and R.J. Prill, Lawrence Berkeley Laboratory, Berkeley, CA

A Comparison of Indoor Air Quality in Conventional and Model Conservation Standard New Homes in the Pacific Northwest: Final Report to the Bonneville Power Administration

LBL-23429; 48 pp. (1987, September)

Ventilation and indoor air quality measurements have been made in 61 new houses located in two regions of the Pacific Northwest. Twenty-nine houses built to Model Conservation Standards (MCS) were compared to 32 Control houses, i.e., new houses built using conventional practices in the region. The MCS houses met the objective of having significantly reduced air leakage area. Yet their total ventilation rate (infiltration plus mechanical ventilation supplied by air-to-air heat exchangers) was the same as the infiltration rate observed in the sample of Control houses. These ventilation rates in both samples were about 0.3/hr. Indoor pollutant concentrations were observed to be only poorly correlated with ventilation rates, an indication that other variables including pollutant source strengths and occupancy effects may be important. Pollutant measurements made in both samples revealed that 11% of the houses exceeded the BPA mitigation action level of 5 pCi/l for radon concentrations, while 16% exceeded the EPA guideline of 4 pCi/l. Thirty percent of the total houses exceed the 100 ppb formaldehyde guideline adopted by many organizations. Indoor pollutant concentrations were seen to vary more between geographic regions than between the two types of house construction.

589

Turk, B.H., D.T. Grimsrud, J. Harrison, R.J. Prill, and K.L. Revzan, Lawrence Berkeley Laboratory, Berkeley, CA

Bonneville Power Administration Indoor Air Quality Measurements in Northwest Residences - Status Report

LBL-19777; 18 pp.; CONF-8505167; Conservation in Buildings: Northwest Perspective, Proceedings of a Conference, Butte, MT, May 19-22, 1985; (pp. 1-33) (1985, May)

Tests were conducted on new and existing homes in the Pacific Northwest to study the effects of weatherization on indoor air quality. One hundred and sixteen existing homes were tested and screened for formaldehyde (HCHO), nitrogen dioxide (NO2), water vapor (H2O), and radon (Rn) using mailed passive samplers. Concentrations ranged up to 136 ppb HCHO, 28 ppb NO2, 9.28 g/kg H2O (60% relative humidity at 68 deg F), and 85 pCi/l Rn. Forty eight homes with measurable levels of NO2, HCHO, or Rn were selected for more intensive monitoring to evaluate the effects of staged weatherization on pollutant concentrations. Pollutants sampled include: HCHO, NO2, H2O, carbon monoxide (CO), respirable suspended particles (RSP), and Rn. Meteorological monitoring occurred concurrent with leakage area measurements using blower doors and ventilation rate measurements using perfluorocarbon tracers (PFT). A separate, 4-week, controlled study evaluated the interactive effects of air leakage reduction and conductive heat loss reduction on the pollutant levels generated by an unvented combustion heating source.

590

Turk, B.H., D.T. Grimsrud, J. Harrison, R.J. Prill, and K.L. Revzan, Lawrence Berkeley Laboratory, Berkeley, CA

Pacific Northwest Existing Home Indoor Air Quality Survey and Weatherization Sensitivity Study: Final Report

LBL-23979; 156 pp. (1988, February)

In a survey of 111 homes in the Pacific Northwest, indoor levels of formaldehyde (HCHO), nitrogen dioxide (NO2), and water vapor were found to be significantly below levels of concern. Indoor radon concentrations were elevated in homes in the Spokane River Valley/Rathdrum Prairie region of eastern Washington and northern Idaho, which has highly permeable soil that encourages convective flow of radon-bearing soil gas. Forty-eight of these homes were studied to evaluate the effects of house weatherization on indoor air pollutant concentrations. Standard weatherization techniques reduced the specific leakage area (SLA), as measured by a blower door in 40 homes by 12.5%, while the reduction in SLA due to wall insulation alone was not statistically significant. House doctoring in five homes resulted in an additional 26% decrease in SLA. Mean ventilation rates, measured with perfluorocarbon tracers (PFT) and uncorrected for environmental conditions, were 0.37/hr before weatherization and 0.39/hr after weatherization. These values were 20% lower than ventilation rates predicted using the LBL model. Good mixing of the indoor air causes uniform distribution of HCHO, NO2, and H2O vapor throughout interiors of the buildings. Respirable suspended particle (RSP) and NO2 concentrations were low in those homes without tobacco smokers or without frequently used combustion appliances and were not dependent on high outdoor levels. Changes in concentrations of all pollutants and ventilation rates were generally small and essentially uncorrelated. Simplified models were developed to evaluate the impact of weatherization on normalized HCHO, H2O vapor, and radon levels.

591

Turk, B.H., J. Harrison, R.J. Prill, and R.G. Sextro, Lawrence Berkeley Laboratory, Berkeley, CA

Interim Report on Diagnostic Procedures for

Radon Control

LBL-23089 (1987, March)

592
Turk, B.H., J. Harrison, R.G. Sextro, L.M. Hubbard, K.J. Gadsby, T.G. Matthews, C.S. Dudney, and D.C. Sanchez, Lawrence Berkeley Laboratory, Berkeley, CA; Princeton University, Princeton, NJ; Oak Ridge National Laboratory, Oak Ridge, TN; U.S. Environmental Protection Agency, Research Triangle Park, NC

Evaluation of Radon Reduction Techniques in Fourteen Basement Houses: Preliminary Results

LBL-25127; 24 pp.; CONF-880679; Proceedings of the 81st Annual Air Pollution Control Association Meeting, Dallas, TX, June 19-24, 1988; Paper No. 88-107.2 (1988, May)

This paper reports the preliminary results of a study of radon control techniques in 14 homes in New Jersey. The study is part of a comprehensive project supported by the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the State of New Jersey, and was initiated to: (1) investigate the fundamentals of soil gas flow and radon entry into buildings and the factors that influence the entry rate; (2) develop a diagnostic procedure for specifying appropriate and effective remedial measures; and (3) better understand the operation of certain mitigation techniques and the parameters that affect them. Reported also are a description of the radon control work that was conducted and a summary of the results of that work.

593
Turk, B.H., R.J. Prill, W.J. Fisk, D.T. Grimsrud, B.A. Moed, and R.G. Sextro, Lawrence Berkeley Laboratory, Berkeley, CA

Radon and Remedial Action in Spokane River Valley Residences: An Interim Report

LBL-21399; 28 pp.; CONF-860606; Proceedings of the Air Pollution Control Association Annual Meeting and Exhibition, Minneapolis, MN, June 22, 1986 (1986, March)

Fifty-six percent of 46 residences monitored in the Spokane River Valley in eastern Washington/northern Idaho have indoor radon concentrations above the National Council for Radiation Protection (NCRP) guidelines of 8 pCi/l. Indoor levels were over 20 pCi/l in eight homes, and ranged up to 132 pCi/l in one house. Radon concentrations declined by factors of 4 to 38 during summer months. Measurements of soil emanation rates, domestic water supply concentrations, and building material flux rates indicate that diffusion of radon does not significantly contribute to the high concentrations observed. Rather, radon entry is dominated by pressure-driven bulk soil gas transport, aggravated by the local subsurface soil composition and structure. A variety of radon control strategies are being evaluated in 14 of these homes. Sub-surface ventilation by depressurization and overpressurization, basement overpressurization, and crawlspace ventilation are capable of successfully reducing radon levels below 5 pCi/l in these homes. House ventilation is appropriate in buildings with low-moderate concentrations, while sealing of cracks has been relatively ineffective.

594
Turk, B.H., R.J. Prill, R.G. Sextro, and J. Harrison, Lawrence Berkeley Laboratory, Berkeley, CA

Intensive Radon Mitigation Research: Lessons Learned

LBL-25910; 23 pp.; CONF-8810134; Radon and Radon Reduction Technology, Proceedings of a Symposium, Denver, CO, October 17-21, 1988 (1988, September)

In the past three years, two intensive radon mitigation projects have been conducted on 15 houses in the Pacific Northwest and seven houses in New Jersey. Both studies collected extensive continuous and periodic data on important house and environmental parameters such as indoor and soil gas radon concentrations, indoor and outdoor temperatures, pressure differentials, ventilation rates, and mitigation system performance. Key findings indicate that soil temperatures can substantially influence the pressure difference that drives radon entry; forced air distribution systems can influence both substructure depressurization and the transport of radon to upper floors; air-to-air heat exchangers and basement overpressurization are successful control techniques in limited situations; subsurface ventilation is often an effective control measure; and resistance to flow for subsurface ventilation systems is greatly influenced by the leakiness of the substructure surfaces that are below grade. General guidance for future studies include an emphasis on research into the fundamentals of radon movement and mitigation.

595
Tye, R.P., Dynatech Scientific, Inc., Cambridge, MA

Assessment of Foam-in-Place Urethane Foam Insulations Used in Buildings

ORNL/Sub-86/56525/1; 75 pp. (1987, October)

Objective of this assessment was to obtain information on the parameters involved in the production and performance of foam-in-place urethane thermal insulation materials and systems. The adequacy of current information on the relevant physical, mechanical, and thermal properties was addressed relating to new applications and climatic areas. Information was obtained from an extensive literature review and discussions with over fifty noted people involved in this field. The principal conclusions are as follows: foam-in-place materials are used extensively in all areas of the USA. The current major use is for new and retrofit spray application on roofs; the materials have significant future potential use for the building envelope and especially for new or modified designs of structure; some problem areas have been identified, in flat roofs and particularly relating to environmental parameters and misapplication; initial cost is a deterrent to use, but true cost effectiveness has not been evaluated; and significant research efforts are on-going or planned but more work is required to develop more appropriate test methods to obtain relevant properties needed to model and validate long term performance.

596
U.S. Department of Energy, Washington, DC

Building Energy Retrofit Research: Multifamily Section Multiyear Plan - FY 1986-1991

DOE/CE/0142; 106 pp. (1987)

A multiyear plan for research and development activities to accelerate, complement, and support private sector efforts to improve the energy efficiency of the existing multifamily housing is being implemented. Planned activities in DOE and the private sector, and consideration of the potential for improved energy efficiency of the building sector is also discussed.

597
U.S. Department of Energy, Washington, DC

Lighting Prescriptive and System Performance Compliance Calculation Program Documentation: Version 10

DOE/CE/0166 (Vol. 4) (1986)

This microcomputer lighting-prescriptive calculation program is part of the Proposed Interim Energy Conservation Standards for new commercial and multi-family and high rise residential buildings. The program may be used for performing the calculations required for the lighting-prescriptive and system performance requirements and compliance calculations in Section 3.4 and 3.5 of the standards. The program will perform calculations for a maximum of 500 separate spaces in a building.

598
Usibelli, A.J., S. Greenberg, M. Meal, A. Mitchell, R. Johnson, G. Sweitzer, F.M. Rubinstein, and D. Arasteh, Lawrence Berkeley Laboratory, Berkeley, CA

Commercial-Sector Conservation Technologies

LBL-18543; 359 pp. (1985, February)

This report describes and documents selected commercial-sector energy conservation technologies and strategies with special emphasis on their application in the Pacific Gas and Electric and the Southern California Edison service territories. The primary topics are space cooling (equipment, loads, systems), air transport, refrigeration, electric motors, electric lighting, and daylighting and fenestration. The report presents cost, energy and power savings, lifetime, product reliability, and related information for each of these topics. Documentation, with field performance data where possible, is also included. Secondary topics, (covered in substantially less detail) are energy management and control systems, natural gas cooking, and natural gas space heating equipment. Gaps in information and future research needs are also highlighted.

599

Valore, R., A. Tuluca, and A. Caputo, Oak Ridge National Laboratory, Oak Ridge, TN; Steven Winter Associates, Inc., New York, NY

Assessment of the Thermal and Physical Properties of Masonry Block Products

ORNL/Sub-86/22020/1; 224 pp. (1988, September)

The objective of this study was to assess the current knowledge on the thermal and physical properties of concrete masonry units and fired clay bricks, and to outline directions for further research. In particular, the authors attempted to uncover the areas where thermal properties data are missing or are questionable, to define the type of testing required to fill in the gaps, and to characterize representative masonry blocks on which the testing should be undertaken. U.S. building codes and standards were examined with respect to the thermal properties of masonry block products. It was concluded that the majority of these codes and standards contain insufficient and/or outdated information regarding concrete masonry units and fired clay bricks, thereby distorting the requirements for walls built with masonry units. A comprehensive bibliography search was performed and the thermal properties data obtained were listed and analyzed. Relationships were derived between oven dry density and thermal conductivity for various concretes, clays, and loose fills. The relationship between moisture content and thermal conductivity was also examined. Areas with incomplete and/or contradictory information were identified. Based on these data gaps and on data quality problems, new testing programs were recommended and improvements to current testing procedures were proposed. The study also suggest low-cost test procedures which could be applied to large numbers of masonry blocks.

600

Van Geem, M.G., Construction Technology Laboratories, Inc., Skokie, IL

Summary of Calibrated Hot Box Test Results for Twenty-One Wall Assemblies

ASHRAE Transactions 92(2); ASHRAE Technical Bulletin TDB-84 (1986)

Alternative wall systems are frequently evaluated by comparing steady-state heat transmission coefficients, such as U- and R-values. Steady-state transmission coefficient do not adequately describe thermal performance under dynamic temperature conditions. Laboratory results of building envelope components tested under steady-state and dynamic temperature conditions can be used to develop methods of more accurately predicting heat losses and gains to the building envelope. The thermal characteristics of 21 wall assemblies, including different types of masonry and wood-frame walls and two standard calibration assemblies, have been measured using a calibrated hot box in general accordance with ASTM C976. Results presenting steady-state, transient, and periodic performance have been assembled in two manuals. This paper summarizes the results.

601

Van Geem, M.G., Construction Technology Laboratories, Inc., Skokie, IL

Measuring Thermal Performance of Wall Assemblies Under Dynamic Temperature Conditions

Journal of Testing and Evaluation 15(3):178 (1987, May)

The calibrated hot box (ASTM Test for Thermal Performance of Building Assemblies by Means of a Calibrated Hot Box (C 976) is used to measure thermal performance of wall assemblies under dynamic temperature conditions. ASTM C 976 does not specify procedures for dynamic testing, or analysis and presentation of results. Dynamic testing procedures used by Construction Technology Laboratories (CTL), including instrumentation of test specimens, derivation of dynamic temperature cycles, acquisition of test data, and presentation of results, are described in this paper. Since 1979, CTL has applied dynamic temperature cycles to 25 wall assemblies using the calibrated hot box.

602
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Calibrated Hot Box Test Results Data Manual - Volume 1, Final Report: Concrete, Masonry, Wood, Veneer-Wood

ORNL/Sub-79/42539/4; 342 pp. (1984, November)

This manual summarizes results from 15 wall assemblies tested under steady-state and dynamic temperature conditions in the calibrated hot box facility. The calibrated hot box provides data on the heat transmission characteristics of full-size wall assemblies under steady-state and dynamic temperature conditions. Steady-state tests are used to obtain average heat transmission coefficients. Dynamic tests provide data on thermal performance under controlled conditions that simulate actual temperature changes in building envelopes. This manual summarizes test results of six concrete masonry walls, two masonry cavity walls, three concrete walls, three wood frame walls, and a brick veneer-wood frame wall. A description of wall geometry and material properties is given for each specimen. The manual presents steady-state, transient, and dynamic (periodic) test results in tabular form, in figures, and in summary tables.

603
Van Geem, M.G., Construction Technology Laboratories, Inc., Skokie, IL

Structural Thermal Break Systems for Buildings: Heat Transfer Characteristics of Lightweight Structural Concrete Walls

ORNL/Sub-84/21006/3 (1988, December)

Divided into five major tasks, this project is the third of three project reports. The primary objective of this report was to develop a Portland cement concrete with sufficient thermal resistance and strength properties to serve as an effective structural thermal break in building envelopes.

604
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Thermal Conductivity of a Recently Developed Lightweight Structured Concrete

Thermal Insulation, Testing and Applications - California, Proceedings of the 1988 Conference, Bal Harbour, FL, 1988 (1988)

A lightweight structural concrete was developed for use in exterior walls of low-rise residential and commercial buildings. The lightweight concrete has a unit weight of 800 kg/cu m (50 pcf), a compressive strength of 13.8 MPa (2000 psi), and a thermal conductivity of 0.23 W/m-K (1.6 Btu/in./hr/sq ft/deg F). Thermal conductivity of the newly developed concrete was measured using three test methods. A calibrated hot box (ASTM Designation: C976) was used to measure thermal conductivity of an 8-in. thick, full-size wall assembly. Thermal conductivity of small concrete sections was measured using two methods: a guarded hot plate (ASTM Designation: C177) and heat flux transducers (ASTM Designation: C1046) and comparison made. The newly developed structural lightweight concrete has 1/9th the thermal conductivity of normal weight concrete and can be used to combine the structural, thermal insulation, and heat storage capacity functions of exterior walls in one element.

605
Van Geem, M.G., and S.C. Larson, Oak Ridge National Laboratory, Oak Ridge, TN; Portland Cement Association, Skokie, IL

Calibrated Hot Box Test Results: Data Manual - Volume II

ORNL/Sub-79/42539/5; 164 pp. (1985, August)

This manual summarizes results from six wall assemblies tested under steady-state and dynamic temperature conditions in the calibrated hot box facility at Construction Technology Laboratories, a Division of the Portland Cement Association. The calibrated hot box provides data on the heat transmission characteristics of full-size wall assemblies under steady-state and dynamic temperature conditions. This manual summarizes test results of two reference "standard" walls, two masonry cavity walls, a concrete wall with insulation board on the outdoor surface, and a wood frame wall.

606
Van Geem, M.G., and S.T. Shirley

Heat Transfer Characteristics of a Recently Developed Lightweight Structure - Concrete

CONF-871203; Insulation Materials, Testing and Applications, Proceedings of the 1987 Conference, Bal Harbour, FL, December 6, 1987

A lightweight structural concrete was developed for use in exterior walls of low-rise residential and commercial buildings. The lightweight concrete has a unit weight of 800 kg/cu m (50 pcf), a comprehensive strength of 13.8 MPa (2000 psi) and a thermal conductivity of 0.23 W/m-K (1.6 Btu/in./hr/sq ft/deg F). Lightweight concretes have not been previously developed with this combination of low density and moderate strength.

607
Verderber, R., Lawrence Berkeley Laboratory, Berkeley, CA

Impacts of Daylighting Design Features on the Choice of Lighting Control Systems

LBL-22043 (1986, June)

608
Verzhbinsky, G., H. Ruderman, and M.D. Levine, Oak Ridge National Laboratory, Oak Ridge, TN

Heat Transfer Characteristics of Insulated Concrete Sandwich Panel Walls

ORNL/Sub-79/42539/8 (1987, September)

609
Veyo, S.E., Westinghouse Electric Corporation, Pittsburgh, PA

Dual-Stroke Heat Pump Field Performance

CONF-841231; Research and Development on Heat Pumps for Space Conditioning Applications, Proceedings of the DOE/ORNL Heat Pump Conference, Washington, DC, December 10, 1984; (pp. 27-36) (1985, August)

An advanced electric heat-pump has been developed for the U.S. Department of Energy. Two nearly identical preprototype systems, each employing a unique dual-stroke compressor, were built and tested in the laboratory. One of these was installed in an occupied residence in Jeannette, PA (near Pittsburgh) on November 24, 1982. It has provided the heating and cooling required from that time to the present. The system has functioned without failure of any prototypical advanced components, although early field experience did suffer from deficiencies in the software for the breadboard microprocessor control system. Analysis of field performance data indicates a heating performance factor (HSPF) of 8.13 Btu/Wh, and a cooling energy efficiency (SEER) of 8.35 Btu/Wh. Data indicate that the heat-pump is oversized for the test house since the observed lower balance point is 8 F whereas 17 F is optimum. Oversizing coupled with the use of resistance heat to maintain delivered air temperature warmer than 90 F results in the consumption of more resistance heat than expected, more unit cycling, and therefore lower than expected energy efficiency. Analysis indicates that if properly sized, the system could deliver an HSPF equal to 8.47 Btu/Wh, and an SEER equal to 9.33 Btu/Wh for the observed weather profile at the field test site. The analysis indicated that with optimal sizing the dual-stroke heat-pump will yield an HSPF 30% better than a single capacity heat-pump representative of high efficiency units in the market place today for the observed weather profile.

610
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Domestic Hot Water Consumption in Four Low-Income Apartment Buildings

LBL-21771; 18 pp.; CONF-860818; Energy Efficiency in Buildings, Proceedings of the American Council for an Energy Efficient Economy Santa Cruz Summer Study, Santa Cruz, CA, August 17, 1986 (1986, June)

Authors investigated domestic hot-water consumption in four apartment buildings (a total of 48 units) managed by the San Francisco Public Housing Authority. In each of the buildings, the performance of the domestic hot water system for six months was monitored. Residents were interviewed about their hot water usage patterns. The shape of the measured profiles of daily domestic hot water consumption was different from profiles published in the literature. We constructed a model of household water consumption was constructed based on reported behavior, and found occupant-reported water consuming behavior to correspond well with measured data: building differences ranged from -19% (the model underpredicts) to 12% (the model overpredicts), and the average difference was approximately 12%. We found educational status to be the only significant sociodemographic predictor of estimated household hot water consumption.

611
Vine, E., and J.P. Harris, Lawrence Berkeley Laboratory, Berkeley, CA

The Experience of Energy Conservation Programs with New Commercial Buildings

LBL-25437; 18 pp.; CONF-880814; Energy Efficiency in Buildings, Proceedings of a Summer Study, Pacific Grove, CA, August 28-September 3, 1988 (1988, June)

A review and assessment of 30 energy conservation programs with new commercial buildings is presented. The types of programs investigated were large-scale demonstrations, financial incentives, rating and labeling, energy awards, design tools, and standards. The report focuses on design assistance programs and examination of available data on market penetration. Major findings and recommendations on designing and marketing new commercial buildings conservation program was presented.

612
Vine, E., J. Sathaye, and A.H. Rosenfeld, Lawrence Berkeley Laboratory, Berkeley, CA

Planning for Oil Overcharge Funds: The California Experience

LBL-20525 (1986, January)

613
Vineyard, T.A., Oak Ridge National Laboratory, Oak Ridge, TN

Review of the 50/50 Programs to Improve Energy Efficiency of Existing Homes

ORNL/CON-184; 37 pp. (1985, August)

The purpose of this study is to compile all existing information about the 50/50 programs. As such, all cost information and other program statistics about the Sentinel and Monegon 50/50 programs are current through January 1985. Section 2 defines the program measures composing the DOE 50/50 program concept, the Sentinel 50/50 program, and the Monegon E-PAK 50/50 program. Section 3 describes the home survey as it was conceived by DOE and practiced by Sentinel and Monegon. Next, the warranty aspect of the Sentinel and Monegon programs is discussed in Section 4. Section 5 summarizes information about the 50/50 dealers, and Section 6 reviews the past evaluations of 50/50 programs. A demonstration project of a shared savings 50/50 program being conducted inn Hennepin County, Minnesota is profiled in Section 7. Final comments about the study are presented in Section 8.

614

Wagner, B.S., and R.C. Diamond, Lawrence Berkeley Laboratory, Berkeley, CA

The Kansas City Warm Room Project: Economics, Energy Savings, and Health and Comfort Impacts

LBL-22752; Energy 12(6):447 (1987)

Although still an experimental technique, the warm room retrofit has the potential for achieving significant energy savings in houses at costs similar to those currently allocated by low-income weatherization programs. This study presents the results from a retrofit project in Kansas City, sponsored by the Urban Consortium in 1985-1986. Nine houses were selected for the study, four controls and five houses that received the warm room retrofit. The houses are all single-family detached structures, occupied by low-income owners (with the owners' ages between 60 and 80 yr), and heated with gas-fired forced-air or gravity-fed furnaces. The warm zone was designed to include the kitchen, bathroom, and one to two additional rooms depending on family size. The costs of the retrofit averages $1425 per house. Analysis included regressions of total gas use versus outdoor temperatures to measure savings, which averaged 26%. An important part of the study was to determine occupant response and the acceptability of the retrofit. The residents participated in the design of the retrofits, and were interviewed after the retrofits were installed to determine improvements in comfort and their satisfaction with the results.

615

Waksman, D., and W.E. Roberts, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Evaluation of Infrared Reflectance as a Technique for Measuring Absorber Materials Degradation

NBSIR-84-2916; 45 pp. (1984, September)

Current ASTM standards concerned with the durability and reliability of absorptive coatings rely on integrated solar absorptance and emittance as the primary methods for assessing changes in absorber optical performance resulting from environmental exposure. This study was undertaken to determine if infrared reflectance measurements are a more sensitive technique for detecting absorber materials degradation. Spectral measurements were made to identify factors that could affect the reproducibility of infrared reflectance measurements and to compare their ability to detect changes with currently used methods for absorber materials. Recommendations are made concerning the use and limitations of infrared reflectance measurements for this purpose.

616

Wallman, P.H., W.J. Fisk, and D.T. Grimsrud, Lawrence Berkeley Laboratory, Berkeley, CA

Exhaust-Air Heat Pump Study: Experimental Results and Update of Regional Assessment for the Pacific Northwest

DOE/BP/60326-1; LBL-23451; 62 pp. (1988, October)

This study focuses on one part of a large project. Phase one of that project assessed Pacific Northwest EAHP performance based on computer simulations. This phase focuses on laboratory evaluations of EAHP performance and a brief update to the preliminary assessment. A later phase will conduct a field study of EAHPs. Researchers monitored the performance of two EAHP systems scheduled for marketing in North America. One system was evaluated with and without operation of an optional fan-coil condenser which can be used to deliver recovered energy to the indoor air. The two units were notably different in one respect: location of the water heating condenser (surrounding the tank versus in the lower quarter of the tank). The study examined inlet air temperature, humidity, and flow rate; water demand volume and schedule; inlet water temperature; and thermostat set points. Primary measures of performance were the coefficient of performance (COP) and the energy savings relative to electric-resistance heating. The meters and other components of the measurement system were finely cross-checked and correlated to minimize errors. In the water-heating mode, the heat pumps were tested in 24-hr runs; for space-heating, tests ran 6 hours because the fan-coil tests reached steady state rapidly. The units were also tested in a combined water- and space-heating mode. The data obtained were used to confirm and update the computer model used in phase one.

617

Wallman, P.H., W.J. Fisk, and R.J. Mowris, Lawrence Berkeley Laboratory, Berkeley, CA

Preliminary Assessment of Residential Exhaust-Air Heat Pump Applications in the Pacific Northwest

LBL-22234; 57 pp. (1986, November)

We provide a technical and economic assessment of residential exhaust-air heat pumps for water heating with option for space heating. Compact one-cabinet heat-pump units containing a hot water tank with refrigerant condenser, exhaust fan, refrigerant evaporator, compressor and controls have recently become available on the U.S. market. The study concerns applications in the Pacific Northwest with three representative locations: Portland, Oregon, Spokane, Washington and Missoula, Montana. Our approach is to simulate system performance for a full year in both a typically-insulated and a well-insulated house. TRNSYS, a transient building system simulation package, is used allowing detailed simulation of heat pump (and other HVAC equipment) operation including control action (on, off and hysteresis effects). Ventilation and energy performance of the heat-pump houses is compared to that of naturally-ventilated houses. Exhaust-air heat pumps are found to provide a nearly constant ventilation rate throughout the year as opposed to the natural ventilation rate that is found to be highly variable. Energy savings realized with the heat pumps range from about 5000 kW/hr in Portland to about 7500 kW/hr in Missoula if the house with the heat pump has a lower average ventilation rate than the naturally ventilated house used as a basis for comparison. An economic analysis indicates that heat pump installations are cost competitive from the homeowner's point of view in the colder interior parts of the Pacific NW. The impact of exhaust ventilation on indoor radon concentrations and radon entry rates into houses is examined using recently-developed models.

618

Wallman, P.H., B.S. Pedersen, R.J. Mowris, W.J. Fisk, and D.T. Grimsrud, Lawrence Berkeley Laboratory, Berkeley, CA

Assessment of Residential Exhaust-Air Heat Pump Applications in the United States

LBL-21514 (1986, June)

619

Walton, G.N., National Bureau of Standards, Washington, DC

AIRNET - A Computer Program for Building Airflow Network Modeling

(1989, April)

In spite of its importance, the analysis of airflows has significantly lagged the modeling of other building features because of limited data, computational difficulties, and incompatible methods for analyzing different flows according to authors. Methods have been developed to analyze airflows in HVAC ducts and to estimate infiltration but the interaction between building HVAC systems and infiltration airflows has seldom been studied. This report describes a computer program for modeling networks of airflow elements, such as openings, ducts, and fans. It emphasizes the numerical aspects of an airflow network method which would provide a unified approach to building airflow calculations. It also discusses the limitations of the method and poorly understood factors that could profit from further research.

620
Walton, G.N., National Bureau of Standards, Washington, DC

Airflow Network Models for Element-Based Building Airflow Modeling

ASHRAE Transactions (1989, June)

In spite of its importance, the analysis of airflows has significantly lagged behind the modeling of other building features because of limited data, computational difficulties, and incompatible methods for analyzing different flows. Methods have been developed to analyze airflows in HVAC ducts and to estimate infiltration, but the interaction between building HVAC systems and infiltration airflows has seldom been studied. This paper emphasizes the numerical aspects of an airflow network method that would provide a unified approach to building airflow calculations. It also discusses the limitations of the method and poorly understood factors that could profit from further research.

621
Walton, G.N., National Bureau of Standards, Washington, DC

Consideration for Advanced Building Thermal Simulation Programs

Building Simulator 1989, Proceedings of a Conference, Vancouver, British Columbia, Canada, June 23-24, 1989 (1989, January)

This report begins with a review of some of the basic numerical methods used in simulation in order to assess the applicability of a more modular approach to the development of building thermal analysis programs. These are discussed with some observations from other fields of study besides building simulation. Two major examples of advanced simulation methods are presented: the use of sparse matrix methods for heat transfer simulation and a modular calculation of building airflows. Their implications on the development of the next generation of building thermal analysis programs are also discussed.

622
Walton, G.N., National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Estimating Interroom Contaminant Movements

NBSIR-85-3229; 26 pp. (1985, November)

Development of infiltration and interroom airflow calculation methods, driven by a concern for indoor air quality have led to a computer simulation of interroom contaminant movement. The model, which assumes fully mixed room air, shows that open doorways provide rapid mixing between rooms in buildings using forced air heating. It also confirms that it is most energy efficient to remove the contaminant nearest its source. Detailed modeling of the variations in contaminant concentration within a room is not presently feasible. The concept of ventilation effectiveness should provide sufficient accuracy and reasonable computing speed to be added to some existing energy analysis programs. Current energy analysis programs with long timesteps tend to run into convergence problems when solving the system performance and interroom airflows simultaneously. Short timestep simulation may be required. The need for computer modeling is demonstrated by the subtle behavior of a very simple system which removes contaminants by forced ventilation.

623
Walton, G.N., National Bureau of Standards, Washington, DC

Modeling Window Optics for Building Energy Analysis

NBSIR-86-3426; 48 pp. (1986, July)

Modeling the optics of windows for the purposes of simulating building energy requirements or daylighting availability is discussed in this report. The theory for calculating the optical performance of conventional windows is reviewed and the simplifications that might commonly be made in creating computational models are analyzed. The author recommends that a building energy analysis program have all models available and efficient use for any given window be made.

624

Walton, G.N., and K. Cavanaugh, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Validation Tests of the Thermal Analysis Research Program

NBSIR-85-3211; 52 pp. (1985, September)

In the study analytical and empirical tests were performed using the Thermal Analysis Research Program (TARP). TARP was found to be very accurate relative to the analytical tests (calculations for simplified conditions) which covered steady and transient conduction, internal radiant interchange, latent loads, and clear sky solar gains. Six one-room buildings with different wall constructions provided data for the empirical tests.

625

Walukas, D.J., and G.E. Courville, Oak Ridge National Laboratory, Oak Ridge, TN

Decision Guide for Roof Insulation R-Value

ORNL-6172; 37 pp. (1985, June)

This report provides a method to estimate the optimum roof insulation R-value (thermal resistance) for a typical Air Force building type with a typical building use schedule and insulation type. The method can also estimate life cycle cost (LCC) differences that result from differences in roof insulation types and insulation R-values. Results from application of the method can be used to verify that a reasonable thickness of roof insulation is used. Estimates of LCC differences can be used to indicate the need for further, and presumably more costly, computer-based building energy use analyses. This report is not a design guide. Criteria in AFM 88-15, AFM 91-36, and ETL 83-11 provide design guidance. Use the material in this report to ensure that roof insulation designs are reasonable based on LCC. In addition, the authors of this report have developed a companion document. Insulation System Basics for Built-Up Roofs (to be published), which provides basic information on the use and general characteristics of various insulations for built-up roof systems.

626

Warren, M., C. Benton, R. Verderber, O. Morse, S. Selkowitz, and J.E. Jewell, Lawrence Berkeley Laboratory, Berkeley, CA; Pacific Gas and Electric Company, San Francisco, CA

Instrumentation for Evaluating Integrated Lighting System Performance in a Large Daylighted Office Building

LBL-20087; 22 pp.; CONF-8510218; Field Data Acquisition for Building and Equipment Energy-Use Monitoring, Proceedings of a National Workshop, Dallas, TX, October 16-18, 1985 (1986, July)

This paper describes instrumentation used to monitor the electrical energy consumption and illumination levels in a recently completed 56,000-sq m office structure in the San Francisco Bay Area. Interfacing of the temperature, electrical, and illumination measurements to the dataloggers is described. A brief description of the building and the issues to be addressed by this monitoring project was given. The instrumentation installed in the building to measure both lighting levels and electric power consumption were described. Typical results that can be obtained with this instrumentation are presented.

627

Warren, M., C. Benton, R. Verderber, O. Morse, S. Selkowitz, and J.E. Jewell, Lawrence Berkeley Laboratory, Berkeley, CA; Pacific Gas and Electric Company, San Francisco, CA

Evaluation of Integrated Lighting System Performance in a Large Daylighted Office Building

LBL-21466; 18 pp.; CONF-860818; Energy

Efficiency in Buildings, Proceedings of the American Council for an Energy Efficient Economy Santa Cruz Summer Study, Santa Cruz, CA, August 17, 1986 (1986, July)

The paper presents a summary of daylighting and electric lighting performance as monitored in several zones of the building. Analysis of detailed measurements on the third floor for four unoccupied days in May indicates that on the brighter south side, the potential for dimming during occupied periods is to 44% of full power. On the dimmer north side of the third floor, the potential for dimming during occupied periods is to 31% of full power based on an eight-day block of data in July. Analysis of detailed measurements during occupied periods indicates that on the third-floor south side the actual average power consumption is 75% of full power over nine-days in May. On the third-floor north side, the actual average power consumption during occupied periods is 50% of full power for eight days in July. Significant potential for daylighting is not being realized.

628
Warren, M., S. Selkowitz, O. Morse, C. Benton, and J.E. Jewell, Lawrence Berkeley Laboratory, Berkeley, CA

Lighting System Performance in an Innovative Daylighted Structure: An Instrumented Study

LBL-20538; 10 pp.; CONF-861109; Architecture and Natural Light, Proceedings of the Second International Daylighting Conference, Long Beach, CA, November 5-7, 1986 (1986, November)

This paper presents conclusions from a one-year instrumented study of an innovative daylighted commercial building in the San Francisco Bay area. The building, a five-story structure housing 3000 employees, has a series of architectural features specifically developed to admit daylight into interior office zones. These are complimented by a continuously dimmable fluorescent lighting system that supplements available daylight under the control of open-loop ceiling-mounted photosensors. Monitored data indicate that the architectural daylighting features of the building are performing admirably and contribute significant daylight to most areas of the building's open plan offices. Field tests have determined that, under manual control, the electric light dimming hardware is capable of dimming to 27% of full power consumption. Operational savings, however, are limited by inappropriate performance of the control system in many of the building's lighting circuits.

629
Wasserman, D.M., and L.N. McCold, Oak Ridge National Laboratory, Oak Ridge, TN

Survey of Installation and Operation Characteristics of Currently Operating Small Cogeneration Units

ORNL/TM-9428; 63 pp. (1985, August)

Small cogeneration systems under 500 kW electrical capacity have the potential to substantially reduce energy consumption in many commercial, institutional, and industrial applications. Whether a cogeneration user realizes, a monetary savings will depend on several factors including installation and maintenance costs of the cogeneration equipment and the reliability of the systems. This study examined these and other characteristics of commercial available small cogeneration systems. Several recommendations made from the study were: (1) small cogeneration systems should be carefully designed with special attention to prevention of engine overheating, (2) untrained personnel should be prevented from modifying or adjusting cogeneration equipment, (3) regular maintenance should be performed by qualified service personnel; and (4) small cogeneration systems should be equipped with an automatic failure notification system in order to minimize downtime when problems arise.

630
Wilde, G.M., Lawrence Berkeley Laboratory, Berkeley, CA

Bibliography of Daylighting Publications: 1977 - 1984

WDA-206 (1985)

631
Wilfert, G.L., et al., Pacific Northwest Laboratory, Richland, WA

Assessment: Proposed Interim Conservation Standard for the Design of New Federal Residential Buildings

PNL-5573 (1986)

632
Wilkes, K.E., Oak Ridge National Laboratory, Oak Ridge, TN

A Model to Predict Heat Flows and Temperatures in Roofs

CONF-890976; Mathematical Modeling of Roof Systems, Proceedings of an International Symposium, Oak Ridge, TN, September 15-16, 1989; 21 pp. (1989)

Models play an important role in the operation of the Roof Research Center at Oak Ridge National Laboratory (ORNL). They increase the efficiency of costly experimentation by guiding the placement of sensors, identifying critical experiments, and extrapolating the results of experimental data to conditions other than those which were tested. Models are essential to developing an understanding of the complex interactions of the thermal, moisture, and mechanical behaviors of roofs. This paper gives a description of the model named STAR (Simplified Transient Analysis of Roofs) that has been developed at ORNL for predicting the heat flows and temperatures within roof systems. The model has several advantages. It is flexible in that it can handle multiple layers of materials having arbitrary thermal conductivities, specific heats, and densities. It can be used to analyze experimental data where boundary temperature data are available, as well as hypothetical cases where only weather data are available. One of the model's main advantages is its availability.

633
Wilkes, K.E., Oak Ridge National Laboratory, Oak Ridge, TN

Models for Roof Thermal Performance

ORNL/CON-274; 78 pp. (1989, July)

A model for predicting heat flows and temperatures within roof system is described. The model called Simplified Transient Analysis of Roofs (STAR), applies to transient one-dimensional heat conduction in multilayer roof systems and is fully coupled to ambient weather conditions.

634
Winkelmann, F.C., Lawrence Berkeley Laboratory, Berkeley, CA

The Electrical Analog: RC Networks for Heat Transfer Calculations

AIP Conference Proceedings 135(1):650-654 (1985, November 25)

A brief introduction to the analogy between electricity flow and heat flow is given and some simple examples of RC networks applied to heat conduction through building walls are described.

635
Winkelmann, F.C., Lawrence Berkeley Laboratory, Berkeley, CA

Advanced in Buildings Energy Simulation in North America

LBL-21489 (1986, April)

636
Winkelmann, F.C., and M. Lokmanhekim, Lawrence Berkeley Laboratory, Berkeley, CA

Sun-control Options in a High-Rise Office Building

Energy and Buildings 8(1):1 (1985)

The DOE-2 building energy analysis computer program has been used to study the life-cycle cost and annual energy use for a wide range of glazing and sun-control options in a 25-story office building with 50% glazing. Four climates, Miami, Los Angeles, Washington, DC, and Chicago, have been analyzed. The architecture, HVAC system, and operating schedules of the building are described. A discussion of weather data, description of glazing and sun-control options, daylighting analysis approach, and an overview of the economics calculation methodology are presented.

637

Wood, D., H. Ruderman, and J.E. McMahon, Lawrence Berkeley Laboratory, Berkeley, CA

Market Share Elasticities for Fuel and Technology Choice in Home Heating and Cooling

LBL-20090 (1986, February)

638

Yajnik, S., and J.A. Rouz, University of Mississippi, Jackson, MS

Determination of Radiative Properties of Fiberglass and Foam Insulations

ORNL/Sub-86/55930/1; 179 pp. (1987)

The spectral radiative properties of 1450(b) high density fiberglass, 1451 low density fiberglass, and expanded polystyrene were inverted from monochromatic directional-hemispherical reflectance and hemispherical directional reflectance data coupled with an analytical model in wavelength range of 4 to 40 microns. An optimization analysis was conducted for the fiberglass insulations to determine the bulk density at which the steady-state heat transfer through fiberglass layer insulation was a minimum.

639

Yarbrough, D.W., R.S. Graves, and D.L. McElroy, Oak Ridge National Laboratory, Oak Ridge, TN

Thickness and Density Measurements for Attic Loose-Fill Thermal Insulations in Eight Cities

ORNL/TM-10414 (1987, August)

Thickness and density data for loose-fill thermal insulation installed in residential attics have been obtained in eight cities during the period 1979 through 1986. The field data provide a basis for estimating the amount of insulation settling that occurs after installation. The field study has progressed through stages of increasing complexity to include: (1) density measurements 1 to 10 years after installation; (2) monitoring of insulation density and thickness with time, starting with installation with time, starting with installation at densities near the manufacturer's recommended value. The first part of the study revealed unexpectedly high insulation densities. The latter parts of the study have shown that settling continues for about 2 years after installation. Sufficient data were collected to construct correlations that can be used to predict final thickness or density values for the products that were tested. The mineral fiber insulations installed near label density showed thickness loss in the range of 6 to 7%, while products installed at densities 20% or more above the manufacturer's recommended value did not settle. Data obtained for loose-fill cellulosic insulation shows settling for at least 2 years that can be correlated with results from the blower-cyclone-shaker test for settled density. This report includes an analysis of the effect of settling on R-value and correlations that are useful for calculating R-values from thickness and density measurements. An experimentally based analysis of the blower-cyclone-shaker test for the settled density of loose-fill cellulosic insulation is also included in this report.

640

Yarbrough, D.W., R.S. Graves, F.J. Weaver, and D.L. McElroy, Oak Ridge National Laboratory, Oak Ridge, TN

The Thermal Resistance of Perlite-Based Evacuated Insulations for Refrigerators

ORNL/CON-215; 25 pp. (1986, September)

The thermal resistances of two side panels which were cut from imported refrigerators and of a single, newly manufactured evacuated packet were measured using a linear heat flow technique. The panels were composites of foamed-in-place urethane surrounding perlite-filled evacuated packets. One panel contained an apparently punctured packet and was found to have a thermal resistance at 300 K in the range 0.617 to 0.950 sq m X kW for 2.54 cm (3.5 to 5.4 sq ft/hr/F/Btu for 1.0 in.). A second apparently undamaged packet had thermal resistances in the range 1.66 to 2.45 sq m X kW for 2.54 cm (9.4 to 13.9 sq ft/hr/F/Btu for 1.0 in.). The internal pressure of the undamaged packet was calculated to be in the range 100 to 1000 Pa by comparing packet thermal properties with apparent thermal conductivities, k sub a, obtained as a function of pressure for the perlite removed from the damaged packet. The thermal resistance for the single evacuated packet was determined by framing the packet with polyisocyanurate of known k sub a and measuring heat flow across the assembly. This yielded a thermal resistance of 18.1 sq ft/hr/F/Btu for 1.0 in. The k sub a values of two domestic perlites and the perlite removed from the punctured refrigerator packet were measured at 300 K and pressures from atmospheric down to about 5 Pa using a radial heat flow technique. Near 1 atm. the k sub a of fine domestic perlite at a density of 246 kg/cu m was 5% above that of the foreign perlite at 225 kg/cu m, but the domestic product had a k sub a up to 45% greater than that of the foreign product under vacuum. The mean particle diameter of the imported perlite was near 13 um, while the mean particle diameter of the domestic product was near 21 um.

641

Yarbrough, D.W., D.L. McElroy, and R.S. Graves, Oak Ridge National Laboratory, Oak Ridge, TN

Thermal Resistance of Roof Panels and In-Situ Calibration of Heat Flux Transducers

CONF-851202; Thermal Performance of the Exterior Envelopes of Buildings - III, Proceedings of the DOE-ORNL-ASHRAE-BTECC Conference, Clearwater Beach, FL, December 2, 1985, 1421 pp.; (17 pp.) (1985)

The dynamic insulation efficiency tester, DIET, in use at the Oak Ridge National Laboratory, ORNL, has been used to measure the apparent thermal conductivities, k, of four board-insulations used in roofing applications. The k's were calculated from steady-state temperature and heat flux measurements. The experimental results were also used to obtain calibration factors for heat flux transducers imbedded in the panels. The heat flux measurements obtained with DIET were used to obtain calibration factors for heat flux transducers imbedded in panels to be used in roof-tests assemblies. The factors relating transducer electrical output to heat flux ranged from 55 to 70% of the manufacturer-supplied factors that were obtained at heat flow rates much higher than the present case. These results demonstrate the need for in-situ calibration of heat flux transducers at heat flow rates near those to be used for thermal performance evaluations.

642

Yarbrough, D.W., D.L. McElroy, and R.S. Graves, Oak Ridge National Laboratory, Oak Ridge, TN

Modeling of Thermal Resistance Test Configurations that use Thin Heaters

CONF-871203; Insulation Materials, Testing and Applications, Proceedings of the 1987 Conference, Bal Harbour, FL, December 6, 1987; (27 pp.) (1987)

The usefulness of a large unguarded thin screen heater as an integral part of a thermal resistance measurement apparatus for insulations has been demonstrated. Thermal modeling of existing and proposed test configurations can be used to establish applicability. HEATING5, a general purpose conduction program, has been used to obtain the temperature distributions encountered in linear and radial heat flow testers with thin heaters. Thermal simulations of the existing screen tester have been used to determine the effects of specimen thickness and thermal resistance on measurement errors. Simulation results were obtained for test configurations in order to provide a basis for design improvement.

643

Yarbrough, D.W., F.J. Weaver, R.S. Graves, and D.L. McElroy, Oak Ridge National Laboratory, Oak Ridge, TN

Development of Advanced Thermal Insulation

for Appliances - Progress Report for the Period July 1984 to June 1985

ORNL/CON-199; 50 pp. (1986, May)

Numerical simulations of the radial heat flow apparatus used to measure the apparent thermal conductivity (k sub a) of powders with high thermal resistance (R) showed that heat losses from the ends of the cylindrical specimen and core heater cause the k sub a of the specimen to be greater than the true value. This effect is large when high-R powders are tested. A radial apparatus 91 cm in length, ORNL-5, were constructed and used to reduce uncertainties introduced by end losses. Numerically derived factors were prepared for use with the relatively short (30 cm) radial heat flow apparatus, ORNL-3, which has vacuum capabilities. Theoretical considerations suggest that radiative transport is powders of the size range available is by absorption and re-emission rather than by scattering.

644

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In Situ Wood Heat Monitoring

CONF-880128; Proceedings of the American Society of Heating, Refrigerating and Air-Conditioning Engineers Winter Meeting, Dallas, TX, January 30-February 3, 1988. American Society of Heating, Refrigerating and Air-Conditioning, Atlanta, GA; ASHRAE Transactions 94(1):1147-1153 (1988)

Infrared radiometers were used to measure the heat output of 100 wood stoves during two heating seasons in homes weatherized by the Hood River Conservation Project. Radiometer readings were correlated to stove heat output using shape factor analysis and the results of calorimeter room tests. The monitoring methodology is described, and the measured heat output is compared with energy estimates based upon the reported wood consumption in these houses. The field efficiencies computed for 35 stoves for both heating seasons were surprisingly lower than the efficiencies expected from laboratory measurement, averaging only 32% in the first year and 23% in the second year. Possible causes for this discrepancy are discussed.

645

Yoder, R.A., G.A. Spolek, and M.P. Modera

Evaluation of a Wood Heat Monitoring Study: The Hood River Experience

Solar '87, Proceedings of the 1987 Annual American Solar Energy Society Meeting, Portland, OR, July 12-14, 1987 (1987)

646

Zarr, R.R., D.M. Burch, T.K. Faison, and C.E. Arnold, National Bureau of Standards, Buildings Physics Division, Gaithersburg, MD

Thermal Resistance Measurements of Well-Insulated and Superinsulated Residential Walls Using a Calibrated Hot Box

NBSIR-86-3398; CONF-8606125; Proceedings of the Annual American Society of Heating, Refrigerating and Air-Conditioning Engineers Meeting, Portland, OR, June 22, 1986; ASHRAE Transactions 92(2B):604-622 (1986, June)

Thermal resistance measurements of two highly insulated residential walls are made using a calibrated hot box operated under winter and summer climatic conditions. The well-insulated wall consists of two insulated wood-frame sections with staggered framing, having a nominal thermal resistance of R-27 hr/sq ft/F/Btu (4.8 sq m/kW). The superinsulated wall is identical in construction, except for additional insulation placed between the two wood-frame sections increasing the wall thermal resistance to a nominal value of R-39 hr/sq ft/F/Btu (6.9 sq m/kW). The measured thermal resistance for both walls is examined as a function of mean wall temperature and compared with predictions using the ASHRAE parallel-path method, the ASHRAE isothermal-plane method, and a finite-difference model with temperature-dependent thermal conductivities. Good agreement between measured and predicted values is obtained using both ASHRAE methods and the finite-difference model. At mean wall temperature above 40 F (4.4 C), the ASHRAE parallel-path method tends to overpredict, while the ASHRAE isothermal-plane method tends to underpredict the overall thermal resistance. The effects of the compression of glass-fiber blanket insulation and nail penetrations on the overall thermal resistance are investigated.

647

Zarr, R.R., et al., National Bureau of Standards, Washington, DC

Calibration of the NBS Calibrated Hot Box

Journal of Testing and Evaluation 15(3):167-177 (1987, May)

A series of calibration tests were conducted in the laboratory in order to determine the overall experimental error and uncertainty for the NBS calibrated hot box. For these tests, 10 cm (4 in.) and 20 cm (8 in.) thick polystyrene wall specimens having independently measured thermal resistances were installed in a support frame and sandwiched between the metering and climatic chambers. The metering chamber was operated at a typical indoor condition for a residence, while the climatic chamber was operated at selected steady outdoor winter conditions. For each of the tests, an energy balance was performed on the metering chamber. The heat transfer that flanks the wall specimen and passes through the support frame was predicted using a finite-difference model. The other heat losses and gains for the energy balance were measured. The residual energy loss of the energy balance of the metering chamber represents the overall experimental error and uncertainty.

648

Zehr, F.J., Oak Ridge National Laboratory, Oak Ridge, TN

The Performance and Economics of Superinsulated Houses

ORNL/CON-148; 217 pp. (1985, June)

The performance and economics of various residential thermal envelope energy-conserving features are analyzed. Variations in external wall construction such as 2 by 4, 2 by 6, double-wall, and strapped-wall are treated. Variations in ceiling insulation, floor insulation, air-vapor sealing, number of window glazings, and window orientation are included. Superinsulation is defined in this study to be consistent with present-day usage and includes high wall and ceiling thermal resistance factors, a well-sealed air-vapor barrier, triple panes, much of normal window area southward, south-facing windows summer shaded, and air-to-air heat exchanger controlled ventilation. The space-conditioning and water-heating loads were determined for a particular thermal envelope for a given climate location by computer methods. Life cycle costs (LCCs) were calculated according to the energy requirements, fuel prices, fuel price escalation rates, and capital and maintenance costs of installed space-conditioning and water-heating equipment. Costs are given in mid-1982 dollars discounted at an annual rate of 3% over a period of 25 years. In addition, incremental costs for houses with various energy-conserving thermal envelope features were determined with respect to a reference house. The results show superinsulation to be economically beneficial to the homeowner for a range of U.S. space-conditioning requirements.

649

Zimmerman, K.H., Oak Ridge National Laboratory, Oak Ridge, TN

Laboratory Test, Design Model Validation, and Parametric Study of a Heat Pump Water Heater

CONF-8410153; Proceedings of the Seventh Heat Pump Technology Conference, Tulsa, OK, October 15, 1984. Oklahoma State University, Stillwater, OK; (pp. VII.1-VII.6) . (1984)

Heat pump water heater (HPWH), units now available are first generation design, assembled with available components which were developed for other uses. Therefore, it is likely that the units can be improved. The objective of the research activities described is to provide an analytical capability that can assist the industry in evaluating the effect of improved components or new design features on HPWH system performance. This experimental and analytical study began by collecting sufficient data to form a data base on the steady-state performance of a residential HPWH unit. The analytical steady-state model was formulated as a modification of an existing heat pump model by developing new subroutines. The experimental data was used to formulate and validate an analytical steady-state model. The model can be used to evaluate recommendations for improvements in component and system design. Early parametric study results are included to illustrate the model's potential usefulness in design studies.

650
Zimmerman, K.H., Oak Ridge National Laboratory, Oak Ridge, TN

Field Data Acquisition for Building and Equipment Energy Use-Monitoring

CONF-8510218; Field Data Acquisition for Building and Equipment Energy-Use Monitoring, Proceedings of a National Workshop, Dallas, TX, October 16-18, 1985 (1986, March)

651
Zimmerman, K.H., Oak Ridge National Laboratory, Oak Ridge, TN

Heat Pump Water Heater Laboratory Test and Design Model Validation

ORNL/CON-173; 85 pp. (1986, March)

A residential separated-type heat-pump water heater (HPWH) unit was tested in a laboratory under controlled environmental conditions. Steady-state tests were conducted over a range of ambient temperatures, relative humidities, and inlet water temperatures. For the ambient temperature rise from 10 to 38 deg C (50 to 100 deg F), the evaporator capacity increased 62%, the condenser capacity increased 67%, and the coefficient of performance (COP) improved 34% (from 1.89 to 2.54). As the HPWH condenser inlet water temperature increased from 46 to 54 deg C (115 to 130 deg F) while the ambient temperature remained 23 deg C (73 deg F), the condenser capacity decreased 4% and the COP declined 14% (from 2.21 to 1.89). Test data were used to form a database on HPWH performance which was subsequently used to validate the HPWH design model. The HPWH design model, a computer program derived from the existing ORNL Heat Pump Design Model, was proven to be capable of predicting the performance of the separated-type HPWH system and is intended to be used in studies concerning the improvement of HPWH performance.

652
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U.S. Heat Pump Research and Development Projects - 1976-1986

ORNL/CON-224; 275 pp. (1987, April)

This document, which is an updated version of U.S. Heat Pump Research and Development Projects published in August 1982 by the U.S. Department of Energy, is a compilation of one-page summaries and publication and patent information for 233 individual research and development projects on heat pumps covering the years 1976 through 1986. The majority of the projects refer to heat pumps in space-conditioning applications. The document is intended to include information on all projects in the United States for which results are publicly available. Ten different indexes are included to aid the reader in locating specific projects.

653
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Heat Pumps: Prospects in Heat Pump Technology & Marketing

(1987)

The purpose of this document is to facilitate information exchange on heat pump research and development (R&D) projects in the United

States. The document is oriented toward individual researchers, technical project monitors, and program administrators who need a greater awareness of the type of R&D work occurring on heat pump technologies. This document was prepared through the efforts of the Building Equipment Research Program at ORNL. This document is a compilation of summaries, publications, and patent information about individual heat pump R&D projects sponsored by DOE, the Electric Power Research Institute (EPRI), the Gas Research Institute (GRI), and a few other organizations. Information on projects started since 1982 along with updated information on completed and current projects that date from 1976 and appeared in a previous document entitled U.S. Heat Pump Research and Development Projects, published in August 1982 by DOE are included.

AUTHOR INDEX

CORPORATE AFFILIATION INDEX

TITLE WORD INDEX

Air

Commercial

Energy

Thermal

KEYWORD INDEX