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ENERGY EFFICIENT BUILDINGS PROGRAM

chapter from

Energy & Environment Annual Report 1977

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ENERGY EFFICIENT BUILDINGS PROGRAM

chapter from
Energy & Environment Division
Annual Report 1977

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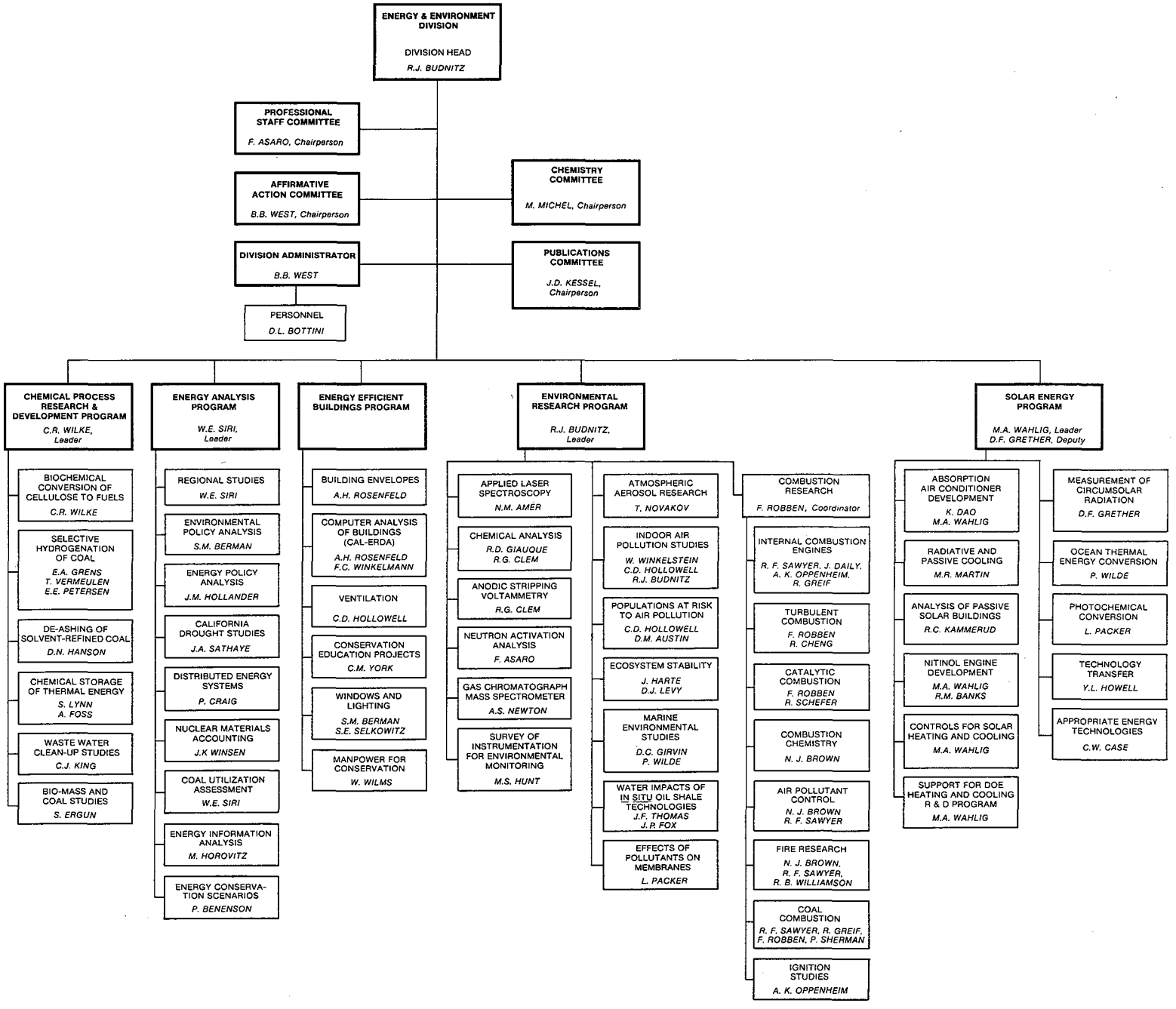

MAY 1978

Energy Efficient Buildings

INTRODUCTION

Research in the Division's energy use and conservation program addresses a broad range of technical and institutional issues that influence the pattern of energy use. These include research into energy use in buildings, and the analysis of energy conservation strategies and measures.

Work on energy use in buildings has concentrated on the following areas:

- Research on the thermal performance of building envelopes. This work includes in-situ studies of heat transfer through building components, as well as measurements of air infiltration. Research on the effectiveness of various retrofits is also being carried out.

- Research on building ventilation and indoor air quality as it affects health. Particular attention is paid to the effects on air quality of energy-saving decreases in ventilation rates.

- Development of CAL-ERDA (DOE-1), a computer program for energy analysis of buildings, which is a tool for design, research, and the evaluation of compliance with building codes.

- Development of a national plan for windows and lighting. Several research projects are underway at LBL, including beam daylighting, window thermal performance, and state-of-the-art fluorescent lighting.

- Demonstration programs that focus on energy conservation in schools, colleges, hospitals and homes.

- Conservation education programs to increase public awareness of conservation strategies.

- Provision of data and recommendations to enable governmental agencies to establish energy-conserving standards for buildings and appliances.

BUILDING ENVELOPES PROGRAM

P. Condon, D. Grimsrud, R. Kammerud, A. H. Rosenfeld
and R. Sonderegger

INTRODUCTION

The Building Envelopes Program began during the second quarter of calendar year 1977 as part of a broad based conservation program titled Building Envelopes and Ventilation (BEV). The program was initiated in response to a need for a systematic study of the building as a whole rather than as a sum of component parts.

The objective of the Building Envelopes portion of the Program is to develop energy-efficient envelope systems through RD&D which will lead to a fundamental understanding of the thermal operation of buildings. The program is divided into two project areas: infiltration of outside air and system thermal performance.

The infiltration projects have the following goals: (a) to identify and determine the magnitude of infiltration sources, (b) to identify and demonstrate retrofit measures, component designs, and fabrication techniques which effectively limit infiltration, and (c) to develop simple measurement techniques appropriate for widespread application. The first goal, source identification, is geared specifically to improving our understanding of the impact on energy consumption of infiltration; computer modeling is an inherent part of this effort. The second goal, infiltration reduction, is closely related to air quality studies which are part of the Ventilation program. Substantial reductions in infiltration rates must be accompanied by increased rates of controlled ventilation. The third goal is directed toward demonstrating techniques of infiltration measurement that would be appropriate for application in code compliance checks or broad-based conservation inspection services.

The system thermal performance projects have the following goals: (a) to correlate field performance, predictive methodologies, and laboratory thermal measurements of envelope systems, (b) to define and/or develop parameters which quantify the thermal performance of envelope systems, (c) to foster the development and acceptance of innovative system designs which effectively improve the thermal performance of the envelope. The first two goals are closely related. They address the need to provide appropriate tools and data to the building designer so that the performance of the completed structure can be reliably predicted. Field performance must be related to laboratory-measurable quantities through methodologies which are applicable at the design and engineering stage. Design and construction guidelines must be developed to insure that the performance of the structure will correspond to the predictions. The final goal is not independent of the first two, but is distinct in implementation. It is expected that this goal can best be met through a combination of design/demonstration competitions and a thorough research program directed at understanding the advantages and limitations of existing building envelope systems.

ACCOMPLISHMENTS DURING 1977

The infiltration projects began with the creation of an annotated bibliography from an extensive literature search of previous work. Emphasis was placed on determining the relative merits of various measurement techniques, on determining the extent of existing infiltration data, and on assessing the state-of-the-art of computer modeling of infiltration. Based on the search, two measurement techniques were selected for the experimental efforts--tracer gas measurements and building pressurization. Subsequently, the measurement systems were specified, hardware fabrication took place, and data analysis software was developed. In cooperation with Department of Energy personnel, the information gathered in the literature search was summarized and presented to the International Energy Agency in the form of a proposed research agenda for their future attention. This research program was directed towards improved techniques for modeling infiltration.

At LBL, residential and small commercial building infiltration projects were chosen for study. These projects have been coordinated with parallel efforts at the National Bureau of Standards, whose research will be concentrating on the commercial building sector. The LBL efforts are oriented towards low-rise buildings where infiltration is driven by both pressure and temperature differentials (wind and stack effects respectively). Infiltration source identification and repair, applicability of simplified measurement techniques (pressurization) and modeling will be emphasized.

The thermal performance projects have been planned and implementation begun. These efforts focus on research and development which will initially lead to a detailed understanding of the heat transfer through conventional building systems (stud walls). A coordinated set of field experiments and testing laboratory measurements have been identified. The goal is to explore the degree of correlation between laboratory measurements of building components and field performance of structures. The in-situ experiments will be used to lead to an understanding of the deleterious effects of air leakage into uninsulated and insulated walls, and also to study the three-dimensional heat flow effects caused by wall studs and by convection in the stud spaces. Additionally, the field data will be utilized in validating a simplified, engineering oriented, one dimensional dynamic model for heat flow in wall systems.

The laboratory measurements are being used to determine the micropatterns of heat flow in stud wall construction. Data from laboratory tests will be used to calibrate a detailed three-dimensional heat flow thermal modeling computer program. The analysis will be important in the development of recommendations for the test procedures to be used in measuring wall systems. Current standard procedures are inadequate and not sufficiently specific to insure unambiguous results. In the long term, a data base of thermal performance properties of multicomponent wall systems must be made available to the building design/engineering community; the measurements obtained in the laboratory experiments will aid in defining the types of data to be included in the data base and will identify the best methods to be used in obtaining the data.

It is anticipated that both the laboratory and field experiments out lined above can be extended in the future to other types of construction (masonry, wall/window/door combinations, etc.). The attention to conventional construction types will be supplemented by demonstrations of innovative construction and by the utilization of unconventional materials and fabrication techniques. The results from this work will be included in the overall data base.

PLANNED ACTIVITIES FOR 1978

During the early weeks of 1978, both the infiltration and in-situ thermal experiments will begin. Detailed studies of the infiltration properties of a single house will be undertaken. There will be three goals: (a) correlation of the measured infiltration rate with measured weather conditions, (b) correlation of the infiltration rate as measured by tracer gas techniques with the leakage rate measured by building pressurization, and (c) identification and quantification of the sources of infiltration, and identification of repair procedures. The detailed studies of infiltration in a single residence will be complemented by a survey of several other buildings so that the generality of the results can be investigated.

The thermal experiments will begin with an examination of the variability of the conductive properties of the envelope of a single building. This will indicate the magnitude of the effects on the performance of the as-built structure due to variations in workmanship. These experiments will be followed by detailed examination both of the effects of convection within stud walls, and of the effects of the studs themselves. The data obtained will be compared to that obtained in laboratory tests.

Laboratory measurements will begin in mid-1978. They will be performed under contract with one of the existing testing laboratories. In early 1978, an assessment of the capabilities, past experience and testing procedures of the testing laboratory will be conducted. Standard procedures for the types of tests to be performed do not currently exist and will be specified by LBL. The data gathered will be analyzed using a three-dimensional finite difference heat transfer code. The calibrated/validated code will be used, together with the experience obtained in the measurement program, to develop recommendations for industry-wide testing procedures of built walls.

VENTILATION PROGRAM

C. D. Hollowell, J. V. Berk, R. G. Langenborg,
C. Lin, and J. H. Pepper

INTRODUCTION

The Ventilation Program, which is funded by the Department of Energy's (DOE) Division of Buildings and Community Systems, is a major component of Lawrence Berkeley Laboratory's (LBL) Energy Efficient Buildings Program. The objective of the Ventilation Program is to conduct indepth research and development on existing and proposed ventilation requirements and mechanical ventilation systems in order to provide recommendations for the establishment of energy efficient ventilation standards and ventilation designs for residential and commercial buildings. LBL will provide both technical and management support to DOE headquarters for ventilation research and development projects.

Approximately 20% of the nation's yearly energy use is for heating, cooling and ventilating buildings. It is expected that energy savings will be realized after implementation of energy-efficient ventilation standards. These standards and design criteria will be based upon a comprehensive analysis (including health and comfort of occupants) of the data base established by this ventilation program. The goal is to minimize the energy needed to provide ventilation while at the same time not compromising human health and comfort. One of the main components of this data base will be data gathered by LBL on indoor air quality. Previous research at LBL concerning combustion generated indoor air pollution indicated that it is essential to consider the impact of reduced ventilation on indoor air quality.[1]

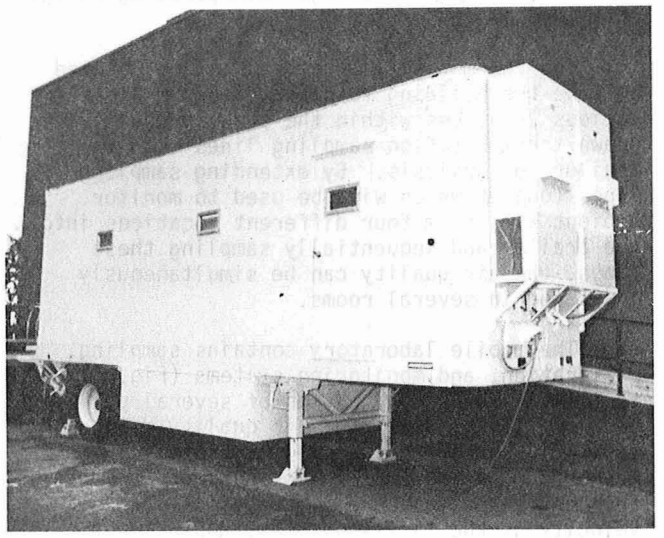

Fig. 1. Exterior view of the EEB Mobile Laboratory. (CBB 770-13104)

ACCOMPLISHMENTS DURING 1977

Work began on the Ventilation Program in April, 1977. In order to meet the objectives of the program, tasks were carried out both in-house at LBL and, to a large extent, by outside contractors who are supervised by an LBL management team.

A mobile laboratory for research and development studies of ventilation requirements and energy utilization in residential and commercial buildings was designed and fabricated by the Ventilation Group in 1977 (Figs. 1 and 2). In support of the field monitoring projects, laboratory and small scale field studies are being carried out to achieve a methodology for characterization and measurement of indoor air pollution. The variables to be measured are:

1) temperature, relative humidity, and air velocity

2) odors

3) toxic chemicals

4) biological species.

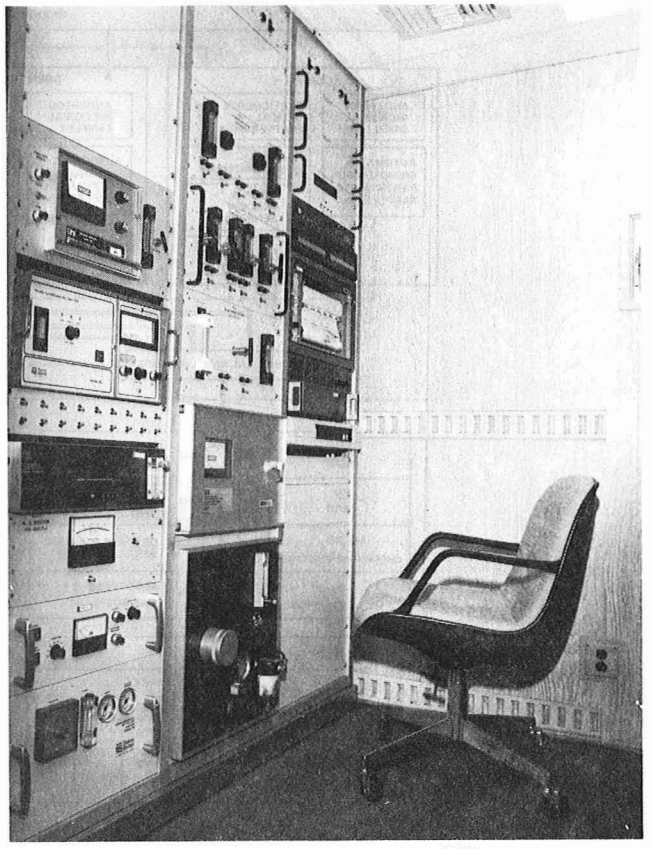

Fig. 2. View of air quality measurement and data acquisition systems in the EEB Mobile Laboratory. (CBB 770-13108)

The Energy Efficient Buildings (EEB) Mobile Laboratory will initially be used in studies of indoor air quality for the establishment of energy efficient ventilation requirements in several types of buildings. These include buildings before and after energy conservation retrofits and new buildings incorporating energy efficient designs.

The EEB mobile laboratory will be located outside the building to be studied and air from various locations within the structure will be drawn through teflon sampling lines into the trailer for analysis. By extending sampling lines (one of which will be used to monitor ambient air) from four different locations into the trailer and sequentially sampling these lines, the air quality can be simultaneously monitored in several rooms.

The mobile laboratory contains sampling, calibration, and monitoring systems (Fig. 3) to measure the concentration of several pollutant gases. Table 1 lists the air quality monitoring capability of the EEB mobile laboratory. The gas parameters, as well as indoor comfort parameters such as temperature, relative humidity and air velocity at the sampling sites, and outdoor meteorological parameters (temperature, relative humidity, wind speed, wind direction and solar radiation) are monitored continuously. Infiltration rates will also be monitored continuously using a tracer gas system developed at LBL in which ethane is injected and monitored under controlled conditions at the sampling site. All of these continuously monitored parameters are recorded on a microprocessor-controlled floppy disk. This information can be transmitted from the field back to LBL via telephone or by physically sending the floppy disk to LBL where it may be read into the LBL system.

In addition to the parameters discussed above, there are several others for which continuous monitoring is not feasible. Some of the contaminants must be collected with gas bubblers and other sampling techniques requiring subsequent laboratory analysis. These contaminants include radon, aldehydes, ammonia, and selected organic compounds. They will require the use of laboratory techniques such as UV spectrophotometry, gas chromatography, liquid chromatography, etc.

The size distribution of the particulate matter in the air will be measured using both an optical scattering instrument and automatic dichotomous air samplers; the latter are also used to collect particulate matter for chemical analysis. The dichotomous air samplers, developed at LBL, separate the aerosols into respirable and non-respirable fractions (below and above 2.5 micron size) using a flow-controlled virtual impaction system which deposits the particulate matter on teflon filters. The particulate matter collected on the filters is analyzed at LBL using beta ray attenuation to measure mass concentration, and x-ray fluorescence to determine chemical composition for 27 elements.

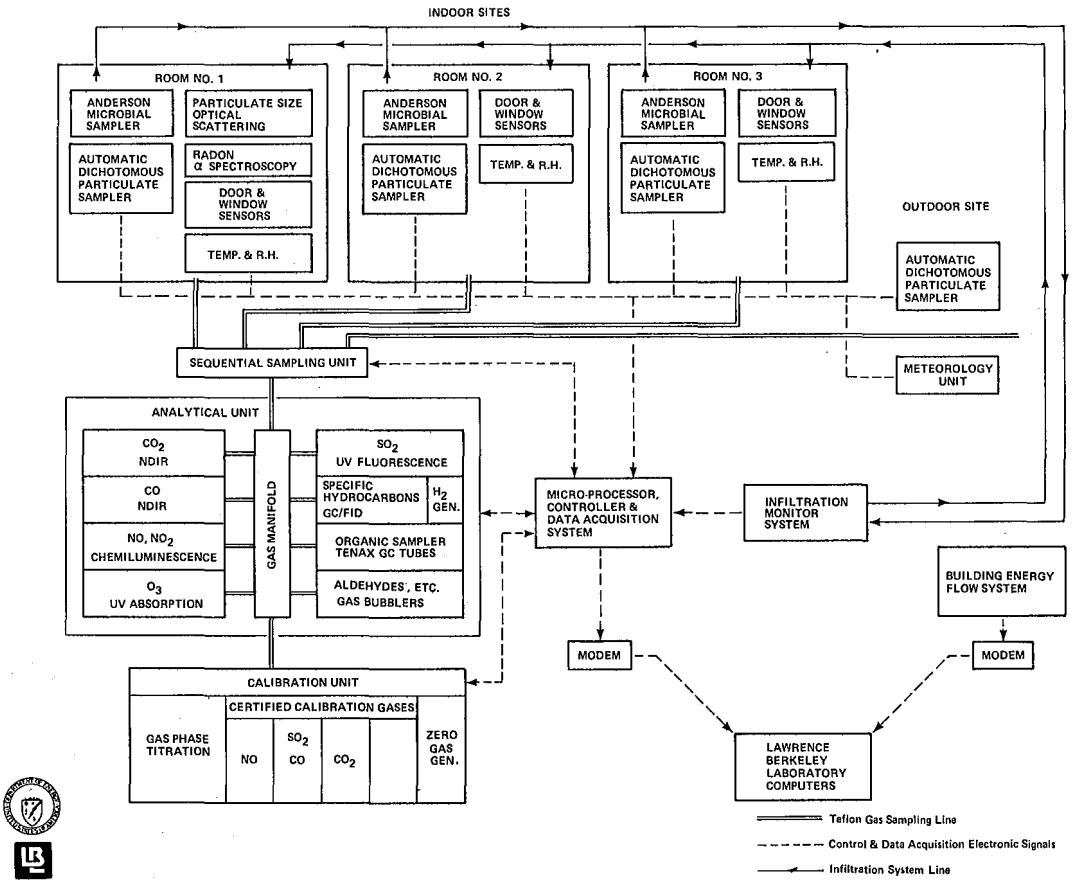

Fig. 3. Energy Efficient Buildings Mobile Laboratory System. (XBL 7712-11471)

Table 1. Instrumentation for Lawrence Berkeley Laboratory Energy Efficient Building Mobile Laboratory.

Parameter	Principle of Operation
FIELD	
Continuous Monitoring Instruments:	
Infiltration	
Ethane (Tracer Gas)	IR
Indoor Temperature, Moisture and Air Movement	
Dry-Bulb Temperature	Thermistor
Relative Humidity	Lithium Chloride Hygrometer
Air Velocity	Anemometer
Outdoor Meteorology	
Dry-Bulb Temperature	Thermistor
Relative Humidity	Lithium Chloride Hygrometer
Wind Speed	Generator
Wind Direction	Potentiometer
Solar Radiation	Spectral Pyranometer
Gases	
SO_2	UV Fluorescence
NO, NO_x	Chemiluminescence
O_3	UV Absorption
CO	NDIR
CO_2	NDIR
Radon	Alpha Spectroscopy
Particulate Matter	
Size Distribution	Optical Scattering
Radon Progeny	Alpha/Beta Spectroscopy
Sample Collectors:	
Gases	
Aldehydes, NH_3	Chemical Reaction/Absorption (Gas Bubblers)
Selected Organic Compounds	Absorption (Tenax GC Adsorption Tubes)
Particulate Matter	
Aerosols (Respirable/Non-respirable)	Virtual Impaction/Filtration
Bacterial Content	Inertial Impaction
LABORATORY	
Gases	
Aldehydes, NH_3	UV-Visible Spectroscopy
Selected Organic Compounds	Gas Chromatography (GC-FID/EC/MS)
Particulate Matter	
Mass Concentration (Respirable/Non-Respirable)	Beta Ray Attenuation
Chemical Composition	
Inorganics	X-Ray Fluorescence (XRF), Photoelectron Spectroscopy (ESCA)
Organics	Gas Chromatography-Mass Spectroscopy (GC-MS) Liquid Chromatography
Bacterial Content	Colony Counting

The bacterial content of the air is measured with inertial impaction devices that deposit particles in specific size intervals on petri dishes. The dishes are incubated for 48 hours and their bacterial colonies are counted. This microbial sampler was developed by the University of California Naval Biosciences Laboratory under contract to LBL.

During 1977 LBL began conducting a literature and equipment survey of existing and advanced contaminant control systems. The specific tasks in progress are:

1) Development of a contaminant control equipment file, edited and categorized by product type for each of 500 suppliers contacted in Fall 1977. A follow-up survey of non-respondents will be initiated in early 1978.

2) Development of an annotated bibliography on ventilation contamination control systems.

3) Installation of a comprehensive data base and numerical data bank utilizing the Berkeley Data Base Management System. Preliminary feasibility has been established, and construction of a pilot bibliographical data base is in progress.

LBL was managing two subcontracts in 1977, both of which will continue into 1978. The University of Minnesota, under a sole source subcontract, is performing a critical literature assessment to establish the current practice and state of the art in hospital ventilation requirements. The intent is to recommend an R&D program for development of a data base adequate to establish energy efficient hospital ventilation standards.

The Naval Biosciences Laboratory (NBL), under a subcontract, has developed a field sampling unit for measuring the microbial burden of air in hospital and educational facilities. This apparatus will aid LBL in evaluating the effects of ventilation and energy conservation measures on the levels, characteristics, and control of the microbial burden of air in hospitals and educational facilities.

PLANNED ACTIVITIES FOR 1978

In 1978 the following sites will be included in the field monitoring study of indoor air quality:

LBL Research House, Walnut Creek, CA
Educational Facilities Buildings, San Francisco Bay Area
Minimum Energy Dwellings, Mission Viejo, CA
Naval Regional Medical Center, Long Beach, CA
Iowa State University Energy Research House, Ames, IA
Iowa State University, Carver Hall Classroom Building, Ames, IA
Fairmoore School, Columbus, OH

In 1978 LBL will continue to manage subcontracts already let in 1977 (University of Minnesota and NBL) and also several new ones. The University of Minnesota will hold an International Working Conference in the winter of 1978 on Hospital Ventilation Standards and Energy Conservation.

It is intended that several new subcontracts will be initiated in 1978. These will be in the areas of odor control and ventilation requirements in hospitals and educational facilities, energy conserving mechanical ventilation systems, and variable ventilation control systems with occupancy/activity sensors.

Work will begin in 1978 on the development and demonstration of variable ventilation control systems using sensors which measure parameters sensitive to building occupancy and activity loads (e.g., sensors for CO_2, CO, enthalpy). The following tasks will be pursued in this project:

1) Estimate the magnitude of energy savings through national implementation of variable ventilation control systems.

2) Determine the cost-effectiveness of variable ventilation control systems with occupancy/activity sensors.

3) Establish the relationships between building occupant/activity loads, ventilation rate, and ventilation requirements.

4) Design and fabricate a variable ventilation control system with occupancy/activity sensors.

5) Demonstrate variable ventilation occupancy/activity-based control systems in various commercial building types.

A detailed study of the mechanical methods of providing ventilation to buildings will reveal areas in which better design can conserve energy. Research, design and development will begin in 1978 to provide innovative, cost-effective, and readily acceptable mechanical ventilation systems for the retrofitting of existing buildings and for application to new buildings.

Mechanical ventilation systems of the simple mechanical exhaust type (with air replacement by infiltration) and the balanced type (with both mechanical supply and exhaust) will be investigated for residential buildings in 1978. A major task will include studies of heat recovery devices as integral components of mechanical ventilation systems in residential buildings.

A ventilation data base will be initiated in 1978 to contain bibliographic and numeric entries, compiling existing data bases from LBL, Naval Biosciences Laboratory and the University of Minnesota. In 1978 it is expected that the logical and physical program design will be completed and that LBL data bases on infiltration and contaminant control will be entered.

Present recommended standards for natural and mechanical ventilation of buildings of various types are contained in the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) Standard 62-73. One of the tasks of the Ventilation Program is to examine and coordinate, on an interagency basis, guidelines for the updating of ventilation standards which could be applied to retrofit and new building applications. It is anticipated that ASHRAE will assist LBL in the development of recommended ventilation standards.

The impact on human comfort and health of energy efficient heating, ventilating and air conditioning systems in buildings will be studied by LBL with the cooperation of government agencies, professional societies and academic institutions. These studies will consider the effect on humans of various physical, physiological and psychological factors.

The culmination of the program activity described above will be a set of recommendations

for the ventilation requirements needed in retrofit applications and new construction. It is expected that these requirements will subsequently be included in the standard building codes issued by local, state and federal agencies.

REFERENCES

1. C. D. Hollowell, R. J. Budnitz, and G. W. Traynor, Combustion-Generated Indoor Air Pollution , presented at the 4th Intern. Clean Air Congress, Tokyo, Japan, May 16-20, 1977.

CAL-ERDA (DOE-1): A COMPUTER PROGRAM FOR ENERGY ANALYSIS OF BUILDINGS*

W. F. Buhl, J. J. Hirsch, M. Lokmanhekim,
H. C. Mitchell, A. H. Rosenfeld, and F. C. Winkelmann

INTRODUCTION

The analysis of energy use in buildings has been facilitated by the development of a new, public domain computer code, Cal-ERDA (to be known as DOE-1 in 1978). Its purpose is to provide both a comprehensive tool to aid in the design of energy conserving buildings, and to analyze existing buildings for opportunities for cost-effective energy-saving modifications. Cal-ERDA (DOE-1) differs from earlier programs in two major respects: (1) it executes faster in the computer, and (2) where earlier programs read data cards filled with numbers punched in fixed format from forms filled in by the engineer, Cal-ERDA (DOE-1) reads a new "Building Design Language" (BDL) designed to increase speed, flexibility, and reliability of input. Special commands and key-words permit the user to specify building properties and parameters such as geometry, construction materials, schedules, heating-ventilating-air-conditioning systems, etc. Environmental data is provided via standard meteorological tapes of hourly weather conditions. Figure 1 is an example of part of a BDL input deck.

ACCOMPLISHMENTS DURING 1977

Cal-ERDA became operational this year and was released for public use in December as Version 1.3. The program is still under development, and additional features are planned to be added in 1978. It consists of four simulation programs:

1. LOADS--Computes hourly heating and cooling loads.

2. SYSTEMS--Simulates the operation of HVAC distribution systems.

3. PLANT--Simulates the operation of the primary heating, cooling, and electrical generating plant.

4. ECONOMICS--Calculates the life-cycle costs of equipment (first cost and operating costs) with account taken of likely energy pieces.

Three applications of the program were completed in 1977:

a. The analysis of the International Energy Agency (IEA) Standard Test Building. This was in support of the IEA effort to compare the results of a number of computer programs for building energy analysis. The results of the intercomparison were inconclusive and a large scatter in the output data was observed.

b. The analysis of nine different non-residential buildings for the State of California. The intention was to determine building energy-use budgets for use by the State Energy Resources Conservation and Development Commission. The analysis was undertaken by Consultants Computation Bureau.

c. A third application was with another IEA test building. Five variations of the test building specifications were used in new comparisons, but a scatter of results still persisted when different computer codes were intercompared.

The first of a series of Cal-ERDA workshops was held on December 7-10, 1977, for 50 managers of facilities connected with the Department of Energy. Some of these people are now using Cal-ERDA by remote operation of the LBL computers.

PLANNED ACTIVITIES FOR 1978

A new version of DOE-1 will be produced to reflect extensive testing of the input language and calculational routines, with improvements in the output reports and error diagnostics. A step-by-step guide to using the program will be written.

Later in 1978 improvements will be made to the PLANT, SYSTEMS, AND ECONOMICS programs. Work will begin on a package to deal with residential analyses.

Although DOE-1 already has solar-energy features (collectors, thermal storage, and heat recuperation), these will be extended during 1978 to include the popular passive solar techniques. The effects of Trombe walls, water walls, and direct gain of sunlight by heavy floors and walls will be included in the package to be developed.

FOOTNOTE AND REFERENCES

*Argonne National Laboratory and Los Alamos Scientific Laboratory are working in collaboration with Lawrence Berkeley Laboratory on this project.

```
*  84 *  INF-2            =DAY-SCHEDULE        (1,24) 0.0                                  ..
*  85 *
*  86 *  INF-WEEK         =WEEK-SCHEDULE       (MON,FRI) INF-1    (WEH) INF-2              ..
*  87 *
*  88 *  INFIL-SCH        =SCHEDULE            THRU DEC 31 INF-WEEK                        ..
*  89 *
*  90 *                            /*SET-DEFAULT VALUES*/
*  91 *
*  92 *                   SET-DEFAULT          FLOOR-WEIGHT = 70.0
*  93 *                                        GLASS-HEIGHT = 4.0
*  94 *                                        GLASS-WIDTH = 5.0
*  95 *                                        GLASS-TYPE = W-1                            ..
*  96 *
*  97 *                            /*BUILDING-SHADE INSTRUCTIONS*/
*  98 *  BUILDING-SHADE TR=0 H=3.5 W=47 XB=2 ZB=7 SAZ=180 T=180                            ..
*  99 *  BUILDING-SHADE TR=0 H=4 W=5 XB=59 ZB=8 SAZ=180 T=180                              ..
* 100 *
* 101 *                            /*GENERAL SPACE DEFINITIONS*/
* 102 *
* 103 *  PLENUM           =SPACE-CONDITIONS    FLOOR-WEIGHT = 5       TEMP = 70            ..
* 104 *
* 105 *  SPACE-1          =SPACE-CONDITIONS
* 106 *                                        PEOPLE-SCHEDULE       =OCCUPY-1
* 107 *                                        NUMBER-OF-PEOPLE      =50
* 108 *                                        PEOPLE-ACTIVITY       =400.0
* 109 *                                        LIGHTING-SCHEDULE     =LIGHTS-1
* 110 *                                        LIGHTING-TYPE         =2
* 111 *                                        LIGHT-TO-SPACE        =80
* 112 *                                        LIGHTING-W/SQFT       =3
* 113 *                                        EQUIPMENT-SCHEDULE    =EQUIP-1
* 114 *                                        EQUIPMENT-W/SQFT      =1
* 115 *                                        INF-METHOD            =2
* 116 *                                        NEUTRAL-ZONE-HEIGHT   =6
* 117 *                                        INF-SCHEDULE          =INFIL-SCH            ..
* 118 *
* 119 *                            /*SPECIFIC SPACE DETAILS*/
* 120 *
* 121 *  PLENUM-1         =SPACE               SPACE-CONDITIONS=PLENUM
* 122 *                                        VOLUME=10000          SPACE-HEIGHT=2        ..
* 123 *
* 124 *      WALL-1PF     =EXTERIOR-WALL       HEIGHT = 2            WIDTH = 100
* 125 *                                        AZIMUTH = 180
* 126 *                                        CONSTRUCTION = WALL-1                       ..
* 127 *
* 128 *      WALL-1PR     =EXTERIOR-WALL       HEIGHT = 2            WIDTH =  50
* 129 *                                        AZIMUTH =  90
* 130 *                                        CONSTRUCTION = WALL-1                       ..
* 131 *
* 132 *      WALL-1PB     =EXTERIOR-WALL       HEIGHT = 2            WIDTH = 100
* 133 *                                        AZIMUTH =   0
* 134 *                                        CONSTRUCTION = WALL-1                       ..
* 135 *
* 136 *      WALL-1PL     =EXTERIOR-WALL       HEIGHT = 2            WIDTH =  50
* 137 *                                        AZIMUTH = 270
* 138 *                                        CONSTRUCTION = WALL-1                       ..
* 139 *
* 140 *      TOP-1        =ROOF                LENGTH = 100          WIDTH = 50
* 141 *                                        X=0   Y=0   Z=10      AZIMUTH = 180
* 142 *                                        TILT=0                GND-REFLECTANCE=0
* 143 *                                        CONSTRUCTION = ROOF-1                       ..
* 144 *
* 145 *  SPACE1-1         =SPACE               SPACE-CONDITIONS     =SPACE-1
* 146 *                                        AREA  =   1056        VOLUME = 8448
* 147 *                                        NUMBER-OF-PEOPLE   =  10.56                 ..
* 148 *
```

XBL 783-7896

Fig. 1. Example of part of the input deck for Cal-ERDA Version 1.3 using the Building Design Language (BDL).

Consultants Computation Bureau (Oakland, CA) is the major sub-contractor to LBL.

"Cal-ERDA Users Manual", ANL/ENG-77-03, October, 1977 (Cal-ERDA/77-1)

"Cal-ERDA Program Manual", Los Alamos Scientific Laboratory, October, 1977 (Cal-ERDA/77-2)

"Sample Cal-ERDA Runs of a 31-Story Office Building and a Medical Center" (Draft), LBL, UCID-3969, UCID-3970, September 30, 1977 (Cal-ERDA/77-3, 77-4)

"A Technical Guide to Energy Computer Programs for Buildings", E. Stamper, E. Smithberg, and R. Jourdain, LBL-6862, December 1, 1977 (Cal-ERDA/77-5)

"Cal-ERDA, A New Program for Building Energy Analysis", LBL-6331 (Cal-ERDA/77-6), to be published in the Proceedings of the First International Conference on Energy Use Management, Tucson, Arizona, October 24-28, 1977.

SAVING ENERGY IN SCHOOLS

A. Heitz and H. Sigworth

INTRODUCTION

This program was initiated by the American Association of School Administrators (AASA) and was funded by the Federal Energy Administration (FEA). Educational institutions are users of considerable amounts of energy, amounting to 5% of the national energy consumption for heating and cooling. Reduction in this energy use would be a significant contribution to a national program for energy conservation. In addition, school districts will benefit by keeping down energy costs. On a per pupil basis these costs have increased by nearly 50% between 1973 and 1975 with continued increases thereafter. School districts have large fixed costs due to the intensity of labor used and so even small savings in operating costs are very desirable.

In 1975 an energy audit and monitoring program was developed to study the energy consumption of schools in the United States. The American Association of School Administrators, with funds from FEA, proposed a demonstration project involving ten schools representative of climatic regions of the United States; the school locations are shown on the map, Fig. 1. Cost effective retrofit measures were selected for these schools with suggestions made for a demonstration project of the effectiveness of such measures.

An effective energy conservation program can be divided into four phases:

1. Conduct an effective energy audit and define energy conservation opportunities with an attractive rate of return on investment.
2. Select and design modifications.

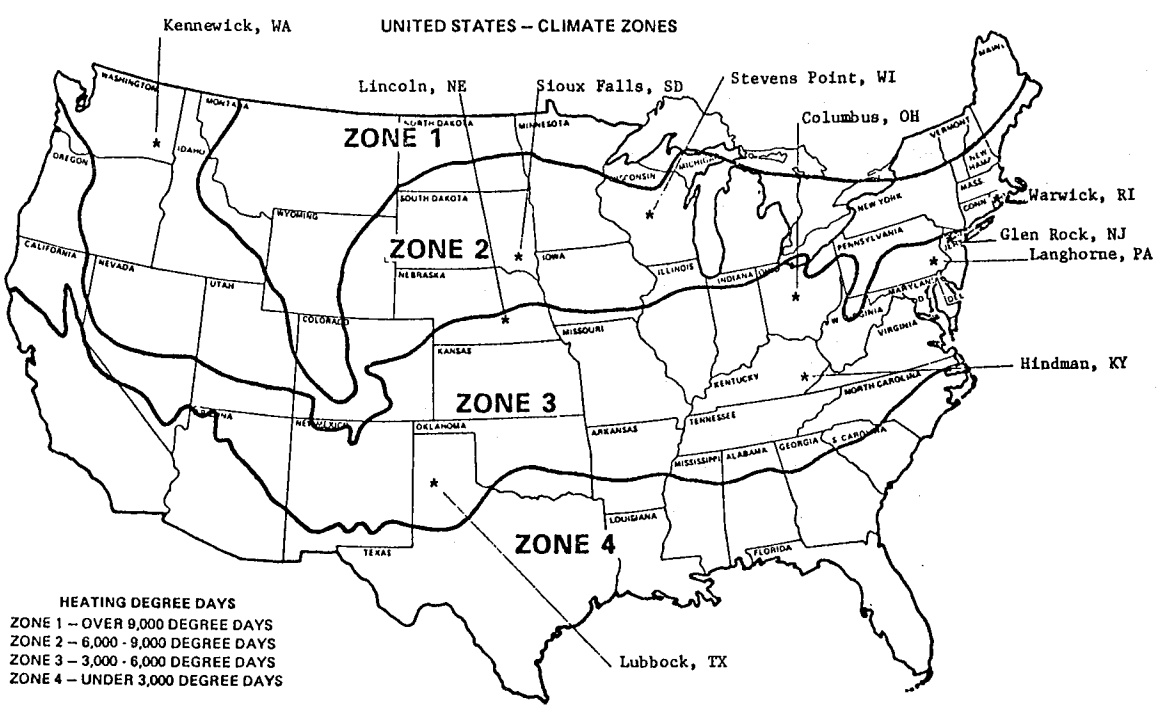

Fig. 1. Demonstration Sites.

3. Install modifications according to engineering designs.

4. Monitor the energy use of the buildings after retrofit and compare with the energy use prior to the modifications.

Phases 1 and 2 of this project had been completed when LBL became involved with the project. The laboratory was given the responsibility of administering the remainder of the project, that is, 3-4. The AASA, which is in close contact with the ten schools, was subcontracted to supervise the engineering work. The Lawrence Berkeley Laboratory has the responsibility of designing and deploying a monitoring system to produce data with which to validate the effectiveness of the retrofit measures. The overall management of the project is also the responsibility of the Laboratory.

The Laboratory involvement in this project provided a means whereby other ongoing programs at the laboratory could benefit from the availability of test sites in diverse climatic regions. In particular, the data expected from the project is being used as source material in verification tests of the Cal-ERDA (DOE-1) program developed to estimate the energy use of buildings. Another group who will benefit from a study of schools are those who are investigating levels of ventilation, and health, in buildings which are to be made energy efficient.

ACCOMPLISHMENTS DURING 1977

A tour of the schools was made to evaluate the results from the first phase of the project, and to collect design criteria for the monitoring systems which would be installed. The ten schools had heating plants utilizing either hot water or steam. Most of the schools used unit ventilators, which were often found to be operating improperly. Many thermostats were found to be functioning poorly. Many districts were short of maintenance support. The modifications which were selected to be implemented at each school are shown in Table 1. Costs, both estimated and actual, are shown for those schools where modifications have been completed.

While these modifications were being implemented, work was continuing at LBL on the design of the monitoring systems. The system selected utilizes a small computer chip to interrogate 32 to 60 input signals which will record such information as air temperatures, flow of water, gas, and steam, and other data relevant for the determination of the energy utilization pattern in the school. Additional binary circuits are used to detect opening and closing of doors or windows. Two classrooms, representative of those in the school, are thoroughly monitored, as is the operation of the central heating plant. Data from the computer system is transmitted over telephone lines to receiving stations at LBL, for storage and subsequent analysis by a computer, and to the AASA district offices for print-out. The whole package has been designed for ease of service in the field by persons not familiar with all the intricacies of the package.

Cost considerations have necessitated the manufacture of two types of instrumentation systems, one being more elaborate than the other. The more complex system is capable of monitoring air quality. It involves chemical and biological measurements in addition to heat and temperature data. The analysis of the air quality data will be the responsibility of the ventilation group whose work is described elsewhere in this report.

In December 1977, it was decided in conjunction with the Department of Energy that a large fraction of the information needed to evaluate the effectiveness of the retrofit proposals could be obtained by installing monitoring systems in three of the ten schools. Energy use in the remaining seven schools will be monitored by a manual system developed by LBL involving careful analysis of meterological and school fuel consumption records.

It was further agreed that there is a need to study an additional school that utilizes air conditioning. This school will be chosen from zones 3 or 4 of Fig. 1.

PLANNED ACTIVITIES FOR 1978

In mid-January, the first monitoring system was installed at the school in Lincoln, Nebraska. The installation of monitoring equipment at Kennewick, Washington and at Columbus, Ohio is expected to be completed by June 1, 1978. The summer will be used to de-bug these systems so that they will be ready for use at the start of the following school year in September.

Selection of the additional school with air-conditioning will be made in the early part of 1978 and a monitoring system will be designed and installed before the start of the school year.

In January data analysis began with information from the school in Lincoln, Nebraska. Energy use patterns for this school are being modelled using the Cal-ERDA (DOE-1) program. The computer runs are being compared with actual energy use in the school before and after the energy saving modifications were made. Similar computer runs and comparisons are being made for all of the other schools in the project.

Table 1. Schools program modifications and costs.

No.	School/Location	Reduce Outside Air	Night Thermostat Set-Back	Roof Insulation	Replace Boiler	Lower Stat Setting	Close Exhaust Dampers	Weather Strip	Increase Boiler Eff.	Reduce Glass %	Summer Equip. Shut Down	Auto-Boiler Control	Improve A/C Use	Improve Indoor Lighting	Reset Air Temperature	Est. Mod. Cost	Act. Mod. Cost
1	Scott/Warwick, RI	X	X	X												42,800	44,885
2	Central/Glen Rock, NJ	X		X	X	X	X	X								43,550	NA
3	Everitt/Langhorne, PA	X			X											21,200	23,320
4	Hindman/Hindman, KY								X	X						13,659	NA
5	Fairmoor/Columbus, OH	X	X						X		X					25,700	NA
6	P. F. Brown/Lubbock, TX											X				1,000	496
7	Eastridge/Lincoln, NB	X	X				X					X			X	10,000	8,577
8	Garfield/Sioux Falls, SD	X	X						X							20,000	23,946
9	Plover-Whiting/Stevens Pt., WI	X											X	X	X	3,900	4,320
10	Washington/Kennewick, WA		X	X					X	X				X		80,425	88,254

COMMUNITY COLLEGES PROJECT

P. C. Rowe and C. M. York

INTRODUCTION

A potential exists for saving energy on community college campuses with the additional advantage of influencing a large number of people through outreach activities. A plan of work has been prepared to implement a program to be carried out in conjunction with community colleges and public utilities.

ACCOMPLISHMENTS DURING 1977

The program got underway at a meeting in December between the Presidents, Business Managers and Physical Plant Managers of five community colleges, together with representatives of LBL and the Pacific Gas and Electric Company. The program plans were met with enthusiasm: colleges have fixed costs which amount to 85% of their operating budgets; of the remaining 15%, 4% goes to fuel bills. Therefore, any savings in this 4% would be very worthwhile financially. Additionally, schools and colleges account for about 5% of the national energy demand and demand reductions of 20% or more would certainly help in our attempts to curtail the total energy demand. We hope that savings of energy of at least 20% at each college should be possible without the outlay of capital funds.

PLANNED ACTIVITIES FOR 1978

Simple energy audits will be carried out at each college and the results shared with the energy teams that will be established at each campus. These teams will represent all of the major constituencies at each campus and will be wholly responsible for the implementation of the conservation strategies that have been suggested either by LBL or by the teams themselves.

Later in the program more extensive technical assistance will be given and comprehensive computer audits made at selected campuses. The usefulness of the Cal-ERDA (DOE-1) program for field use at colleges will be assessed at this time.

The plan of work will be extended later in 1978 in anticipation of a statewide program. We hope to be able to help draw up guidelines with the State Community Colleges Chancellor's Office to enable them to choose between retrofit options that may be funded with federal monies. Both the Association of Physical Plant Administrators and the American Association of Community and Junior Colleges will be kept closely informed of our activities as liaisons with these organizations strengthen.

HOSPITALS PROGRAM

C. D. Hollowell and M. Chatigny

INTRODUCTION

The Hospitals Program which is funded by the Department of Energy's (DOE) Division of Buildings and Community Systems is a major component of Lawrence Berkeley Laboratory's (LBL) Energy Efficient Buildings Program.

It has been estimated that, in the United States, hospitals consume approximately 15% of all energy used in commercial structures. Approximately 50% of this energy is used for heating, ventilation and air conditioning systems. Hospitals have been selected for special study because of their relatively large energy use and also because of the widely varying ventilation standards used in these institutions. It is expected that the establishment of a consistent set of ventilation standards in hospitals will lead to significant energy savings.

The Hospitals Program includes research and development in evaluation and control of the hospital air environment; assessment of the effects of energy conservation measures on the patient care environment; identification of hospital activity areas which are most suitable for introduction of cost-effective conservation measures that will not compromise the patient care environment; and collaboration with ongoing energy conservation efforts of other government agencies and professional organizations to permit rapid dissemination and acceptance of the recommendations of this program. Pertinent knowledge gained in other areas of the LBL Energy Efficient Buildings Program, e.g. ventilation, lighting, and building envelopes, will also benefit the hospitals program. With recognition of the primary need for a strong multi-agency coordinating role by DOE, this program is seen as filling a need for rapid development, testing, and application of new and existing technology to hospital energy conservation.

The project areas of the Hospitals Program may be described as follows:

(1) Assessment of the effects of energy conservation measures on environmental quality including air chemical content, microbial burden, odors, and comfort in existing, retrofitted, and new "energy efficient design" hospitals.

(2) Development, review and acceptance by user and regulatory agencies of augmented, cost-effective energy conservation measures that may have an impact on hospital design and operating procedures.

(3) Rapid transfer of advanced energy conservation technology in practical format to users.

ACCOMPLISHMENTS DURING 1977

Work began on the Hospital Program in August, 1977. The Energy Efficient Buildings Mobile Laboratory, which is described elsewhere (see "Ventilation Program") has been designed and fabricated by LBL for studies of indoor air quality in hospitals and other buildings. The first hospital to be studied with this mobile laboratory will be the Naval Regional Medical Center at Long Beach, California.

LBL was managing two subcontracts in 1977 which involved energy conservation research and development in hospitals. The University of Minnesota, under a sole source subcontract, is performing a critical literature assessment to establish the current practice and state of the art in hospital ventilation requirements. The intent is to recommend an R & D program for development of a data base adequate to establish energy efficient hospital ventilation standards.

The University of California Naval Biosciences Laboratory (NBL), under a subcontract, has developed a field sampling unit for measuring the microbial burden of air in hospitals. This apparatus will aid LBL in evaluation of the effects of ventilation and energy conservation measures on the levels, characteristics, and control of the microbial burden of air in hospitals.

PLANNED ACTIVITIES FOR 1978

The work proposed for 1978 is grouped in the three general areas described above.

(1) Efforts in 1978 will include a DOE-1 computer program energy utilization study of the Naval Regional Medical Center, Long Beach, California. In addition, LBL will be collaborating with the Navy in the design of an in-situ system for monitoring energy flow in selected functional areas of the hospital. The monitoring of existing indoor air quality in several functional areas (e.g., wards, pediatrics, kitchens, etc.) in this hospital is also planned in order to provide baseline data for comparison with subsequent data in 1979 following retrofit.

(2) Efforts will include preparation of a report summarizing a meeting of an "international experts" group to be held by a subcontractor, the University of Minnesota. The University of Minnesota will review current hospital HVAC standards and practices of the U. S. Department of Health, Education and Welfare (HEW), the American Hospital Association (AHA), and other groups, and will develop recommendations for energy conservation measures compatible with both good patient care and good engineering practice. This meeting will be followed later in 1978 by an LBL/DOE-sponsored working group meeting of HEW, AHA, the Department of Defense, the Veteran's Administration and other hospital operators or regulators, where the recommendations and practical aspects of their implementation will be considered. Concurrently, LBL will subcontract a study to examine energy conservation practices in hospital water usage (kitchens,

laundries, boilers, etc.) and the cost-benefits limitations imposed by sanitation requirements.

(3) Efforts in 1978 will be directed towards the establishment of LBL as a coordinating and information disseminating center for energy conservation practices in hospitals. We will establish a permanent working group, consistent with meeting schedules of pertinent national societies (American Hospital Association, American College of Physicians and Surgeons, American Institute of Plant Engineers, etc.), and co-sponsor at least one short symposium on energy conservation. It is anticipated that the major effort in this area for the remainder of 1978 will be to develop a technology transfer program on energy conservation in hospitals.

500 HOMES: THE ENERGY INSPECTION SERVICE

A. Meier and A. H. Rosenfeld

INTRODUCTION

A number of reports from LBL and other institutions have estimated the potential energy savings through residential retrofit measures. We have carried this research two steps further. First, we determined the conservation potential in real homes. Then we attempted to persuade the occupants that such measures were indeed worth doing. At the same time, we sought the most effective means of conveying energy conservation information to the occupants. A trained inspector can often find opportunities while conducting a 90 min energy audit to reduce the home's energy use (typically 700-1100 therms/year) by as much as 80 therms/year with no investment. Most homes inspected could reduce their energy use from 10-40% by investing in conservation measures with a return greater than 20%. Several new conservation measures were discovered during the inspections.

The Energy Conservation Inspection Service was a collaborative effort involving LBL, Pacific Gas and Electric Co. (PG&E), the California Energy Commission and the University of California (UCB). Ten conservation inspectors were trained at UCB during the spring quarter, 1977. They were the top 10 out of 30 students enrolled in a course entitled Energy and Resources 199. An intensive publicity campaign solicited homes for inspection in the early summer. Over 50 Berkeley homes requested inspections by the cutoff date. Half were actually inspected while the remaining half received a literature packet which included a "do-it-yourself conservation guide." PG&E, the local utility, gave us the past (and will provide the future) energy consumption for the homes; this will enable us to determine the relative effectiveness of the inspection versus the informational materials alone. Including a control group, more than 750 homes are involved in the study.

A typical inspection lasted 1-1/2 hr. The inspector usually discussed the resident's energy use over the last year for 10-45 min. Many of the unique social aspects of that household, which were important in understanding its energy use, surfaced in this conversation. The inspection then followed. Back at the office, the inspector prepared a "conservation prescription." This included suggested conservation measures, their cost, expected annual savings and payback time. The prescription also included local stores and contractors where the devices or services were available.

In many cases the inspector, at the request of the occupant, turned off the furnace pilot light, closed ducts to unused rooms and set back the hot water heater thermostat by as much as 40°F. These combined no-cost measures often saved the residents an estimated 80 therms (about $20) a year.

We found that conventional degree-day calculations vastly overestimated savings from insulation and storm windows. In many homes, the mild Berkeley winters and the residents' minimal heating habits made these conservation measures not cost effective. Other measures, such as weatherstripping, insulation blankets for hot water heaters and reduced or fluorescent lighting often appeared more attractive in terms of return on an investment. We were surprised to discover that over half of the fireplaces lacked dampers. This could result in winter heat losses of up to one therm per day.

If the measures recommended in the prescription were followed, the houses would probably reduce their total energy use by 10-40%. Most houses' savings were on the lower end but this may be due to the self-selection of the sample; we suspect that we inspected homes whose occupants had already adopted many more conservation measures than in average San Francisco Bay area homes.

In 1978, we shall monitor the control group's energy use to determine the most effective techniques of implementing energy conservation.

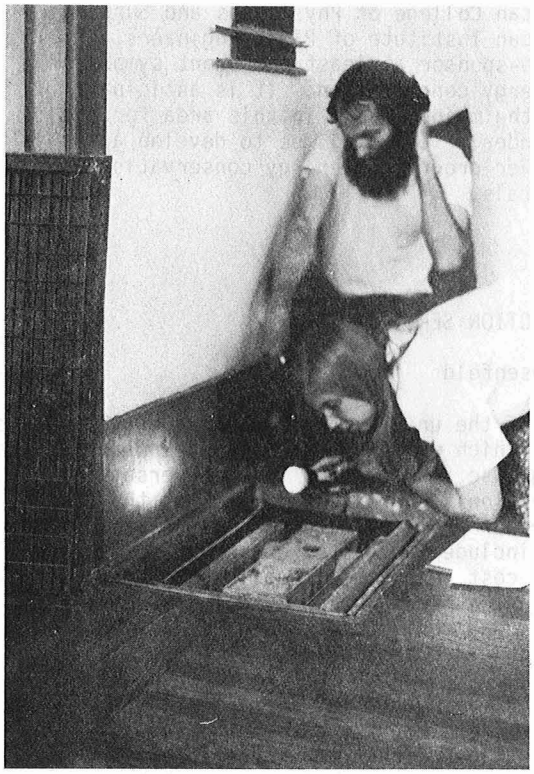

Fig. 1. Many Berkeley homes are heated with gas floor furnaces, which when they are not in operation (most of the time) are sources of considerable quantities of cold outside air. (XBB 783-3191)

Fig. 2. An open damper in the chimney permits a draft which sucks $25 to $40 worth of the hot air out of the home each season. Accordingly the students were instructed to label the damper position--open vs closed, so that the homeowner would be reminded to close the damper after the fire is out. But of the first 60 homes inspected, 48 had no dampers at all. A retrofit damper can be made for about $10. There seems to be the possibility of a small industry here. (XBB 783-3188)

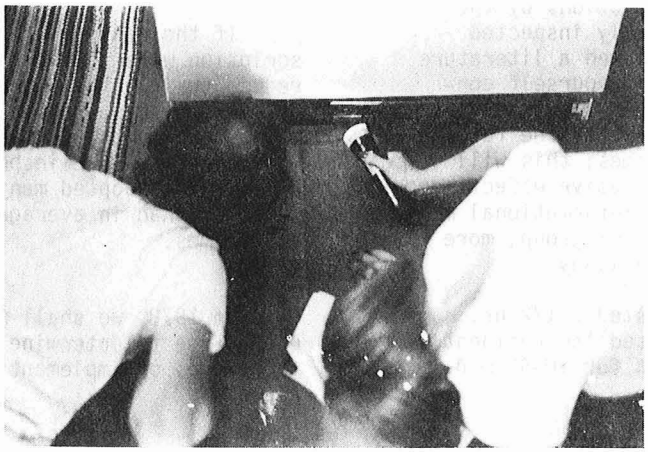

Fig. 3. Doors and gaskets on a refrigerator can easily be adjusted to seal properly. (XBL 783-3190)

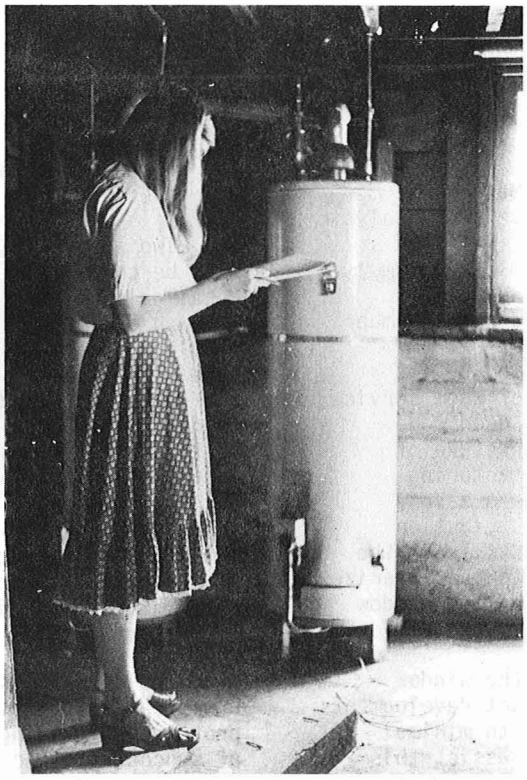

Fig. 4. Reducing the water heater thermostat setting from 150°F to 120°F can save $10 of gas each year. Or $6 of insulation will accomplish the same thing. (XBB 783-3189)

Photo credit to be given to Jean-Claude Dercle

ENERGY EFFICIENT WINDOWS PROGRAM

S. Berman, S. Selkowitz, R. Verderber, and J. Klems

In the latter quarter of 1976, we initiated a program to plan, manage, and conduct an Energy Efficient Windows Research Program at LBL. Funding was provided from the Consumer Products and Technology (CPT) Branch of the Department of Energy. This branch is charged with supporting research, development, and demonstration (RD&D) activities in energy conservation that will:

- accelerate the efforts of private industry
- complement the efforts of private industry
- foster the acceptance of energy saving technology
- maximize the effectiveness of energy use
- minimize adverse socio-economic and environmental impacts.

The Energy Efficient Windows Program at LBL is designed to further these CPT goals. The potential impact of this program on total national energy consumption is large. Approximately 20% of annual consumption is used for space conditioning of residential and commercial buildings, and about 25% of that figure is required to offset loads resulting from windows. Thus 5% of national energy consumption, 3.5 quads annually, or 1.7 million barrels of oil per day equivalent are tied to the thermal performance of windows. Although the conservation potential is enormous, there are significant obstacles to achieving that potential. Recent studies of problems concerning diffusion of innovation into the building industry suggest that in the area of energy conservation, the development of technically usable, energy conserving products and design practices will not necessarily be sufficient to guarantee their acceptance, their utilization, or their effective impact in reducing energy consumption. The Energy Efficient Windows Program has initiated efforts that not only will develop and commercialize innovative and effective window designs, materials and accessories, but will also ensure that they are recognized, accepted and utilized by design professionals and the public at large. The LBL role encompases overall program planning and assessment of research priorities, technical management of research activities subcontracted to private sector firms, and an in-house LBL windows research program.

ACCOMPLISHMENTS DURING 1977

Program accomplishments have been divided into two major areas: (1) program planning, management and support activities, and (2) materials, processes and prototype developments.

In its Program Planning and Management role, LBL plays a vital integrative and catalytic role. The process of formulating short and long term goals and building an RD&D program around them is complicated by the nature of the "window" industry. Although a small number of large firms manufacture glass, aluminum- and wood-framed windows are sold by a vast number of small businesses, most of whom service local markets. Some progress has been made in constructing a model of the structure of the window industry. On the manufacturing end, we have gathered information on sales volumes, mark-up patterns, and distribution networks in the glass/window industry. At the user end, we have developed data to characterize residential and commercial buildings by window area and type as a function of climatic region.

A further characteristic of the window industry is that significant product developments can be generated by small firms with minimal resources. We have endeavored to assist this process by developing a Windows Review which will be circulated widely through the professional community (architects, engineers, manufacturers, inventors, suppliers, code officials, researchers, etc.) to report on latest developments, patents, new materials and products, legislation, publications, etc. Initial response to the concept has been positive and a first issue will be published at LBL in Spring, 1978.

A Building Technology Laboratory has been set up in the College of Environmental Design of the University of California, Berkeley, to support research and development activities, to provide independent tests and evaluations of materials and products submitted by subcontractors, and to permit evaluation of new products being introduced to the marketplace. Window measurement apparatus and capabilities, in place or under construction, include: a calibrated hot box, an infiltration test station, emittance measurements, a solar calorimeter, and spectrophotometers for measurements of solar optical properties of glazing materials. A wide range of commercially available windows have been purchased for demonstration, inspection, and test.

Laboratory testing capabilities described above are all steady state measurements of static materials and devices. A major philosophical thrust of our program is the use of managed window systems, windows whose thermal/optical properties are changed (manually or automatically) over time. To test the performance of such devices, we have designed a Mobile Window Testing Facility. This unique facility will allow us to test net window thermal performance (combined infiltration, conduction/convection, radiation effects) as a function of climate and window orientation over many daily test periods. The four test cells can be configured to simulate a range of building insulation levels as well as a range of building thermal capacities. Results from this test facility should provide good comparative results on which to base assessments of window performance, and against which analytical models can be validated.

Two analytical efforts are underway and will be completed in 1978. The first is a detailed model of the resultant net heat transfer through a window assembly composed of an array of glazing elements and optical coatings. This model will be used to characterize the performance of window components. In order to determine the effectiveness of window management strategies, the performance of the windows must be assessed in the context of the performance of the remainder of a building. For these studies, we have utilized the CAL-ERDA Building Energy Analysis Program (DOE-1) and are modifying the program to incorporate a variety of window management strategies and to allow us to model new window designs and materials.

The development and commercialization of new materials, production processes and window prototypes is being supported through a variety of subcontract and in-house research efforts. These include:

Heat Mirror Commercialization. A heat mirror is an optical coating, applied to a glass or plastic glazing material, which transmits the full solar spectrum but reflects long wave infrared emitted by room temperature surfaces. By reducing the radiative component of thermal losses, the heat transfer coefficient of a single or double glazed window is approximately halved. Heat mirror coatings with good optical/IR performance have been produced by Suntek Research Associates by production techniques which appear to be cost effective if the material is produced in large volume. The abrasion and corrosion resistance of the coatings is not yet sufficient to guarantee long life in an exposed position. Subcontracted work is now underway to produce durable overcoats which do not degrade the IR reflectivity of the heat mirror coating.

The cost and performance of several large scale, high volume, thin film deposition techniques were examined in a small subcontract with Sputter Films, Inc. An existing electrically conducting polymer utilizing a thin gold coating was examined by its manufacturer, Sierracin Corporation, to determine its suitability and cost effectiveness as a heat mirror. Contacts have been made with a number of other firms with interests in producing or utilizing heat mirror films in energy conserving window products. Several efforts are in progress to assess marketing approaches which are most likely to lead to early consumer acceptance. Heat mirror may ultimately be sold in a tinted or reflective form to provide some glare and solar control, with the additional advantage of building upon consumer experience with solar control films. Performance of several different heat mirror configurations combined with solar control

properties will be studied to determine the relative benefit of summer cooling load reduction compared to some loss of winter passive solar gain.

Optical Shutter. An ideal window should have optical properties which change in response to environmental stimuli based upon requirements for thermal and visual comfort within a given building. A variety of mechanical optical shutter devices are available (blinds, shades, shutters, etc.) to perform such functions. The availability of a glazing coating or glazing material which incorporates thermotropic or thermophototropic qualities would be a useful extension of the range of optical shutter mechanisms. A chemical gel which is transparent in its "cool" state and a milky white with high reflectivity in a "hot" state has been developed by Suntek Research Associates and was the subject of extensive testing and development under an LBL subcontract. A manufacturing facility for volume production was conceptualized and product costs were estimated. Although measured performance and durability were good, estimated production costs were sufficiently high to cast doubt on its marketability in its present state. After a review of other candidate optical shutter mechanisms in 1978, LBL will initiate further development efforts in this program area.

Selective Reflectance Coatings. Reflective and/or tinted glass is widely used in many commercial buildings to reduce solar impact and thus energy requirements for air conditioning. Glazing with very low shading coefficients may reduce the opportunities for utilizing available daylight and thus increase electrical lighting energy requirements.

Since approximately one half of incident solar radiation is short wave infrared which contributes nothing to illumination, an optical coating with selective reflectance properties could ideally reduce cooling load by 50% without reducing available illumination. Such coatings are being developed under subcontract by Kinetic Coatings, Inc., using novel ion beam sputtering techniques which produce very durable, weather resistant coatings. This will allow the coating to be applied to the outside of a window where it will function more effectively in a solar control mode. A wide range of selective reflectance coatings and protective layers have been produced and tested for both optical performance and weatherability. In 1978, efforts will be supported to investigate deposition techniques which will allow the sputtering system to be scaled up to a viable production process. Sample preparation and weathering tests will continue throughout the year.

Convection Suppression Window Prototypes. Double glazed windows frequently incorporate venetian blinds or similar devices between the glass planes for light and glare control and to provide privacy. They also reduce heat loss although the design of the devices has not been optimized for that purpose. It is possible to produce double glazed windows with heat transfer rates approaching those of insulated walls by the use of a mechanism in the air space which segments the airspace in such a way as to suppress convective transport. The Mechanical Engineering Department at the State University of New York, Stonybrook, is investigating the design and performance of such mechanisms. Prototypes have been built and tested with a thermal resistance of R5 in an open mode and R10 in a closed mode. Energy loss measurements are being made using a novel heat transfer gage and in 1978 interferometric techniques will be used to visualize convective transfer patterns. Candidate mechanisms will also be studied in 1978 to predict solar gain and an assessment will be made of the impact of these devices on the view from a window.

PLANNED ACTIVITIES FOR 1978

Most existing projects will be continued in 1978 and expected activities have been summarized. A major new program solicitation entitled "Innovative Window Systems" will be initiated in 1978. Unlike the more sophisticated materials development efforts described previously, this program will support development and demonstration of near term, low risk, innovative, energy efficient window systems.

ENERGY EFFICIENT LIGHTING PROGRAM

S. Berman, S. Selkowitz, R. Verderber, J. Klems, and R. Clear

Lighting now accounts for 20% of the electrical energy generated in this country every year or about 5.5% of total U.S. energy consumption. This amounts to some 400 billion kilowatt-hours of electricity, broken down by end use sector as follows:

Residential Use	20%	Schools	7%
Stores	19%	Streets and Highways	3%
Industrial Use	19%	Other Indoor Uses	14%
Offices	10%		
Outdoor Uses	8%		100%

A comprehensive conservation program for research, development and demonstration to improve lighting efficiency, while maintaining desired visibility, could have immediate and lasting benefits in terms of reductions in the energy consumption of our nation's building stock, and in the costs to building owners and users incurred by this consumption.

We estimate that approximately 40% of the electrical energy consumed by lighting, or about 8% of total electrical sales, could be saved by

a concerted near-term conservation effort. Additional peak power savings of a large, but undetermined, magnitude will accrue. These results could be expected from a program based upon (1) cost effective substitution of currently available, energy efficient design practices and products in place of less efficient choices, (2) operation and maintenance of lighting systems consistent with sound energy conservation practices, (3) provision of the appropriate design guidelines for increased use of natural lighting where applicable to displace electrical consumption, and (4) rapid commercialization of new energy efficient products now entering the marketplace. The LBL lighting research program is designed to generate additional conservation options in all of these areas. More detail on the philosophical foundations of this conservation commercialization program is provided in the description of the Energy Efficient Windows Program.

ACCOMPLISHMENTS DURING 1977

Daylighting Studies

Electric lighting represents 25% to 50% of the total energy consumption in many major office buildings. Many office spaces within fifteen feet of an exterior window could be partially or wholly daylit for a significant number of working hours per year. A photocell controlled fluorescent fixture was installed in a small perimeter office and initial observations indicate that the lights are off approximately 80% of the working hours. There has been a renewed interest in promoting the use of daylighting practices to reduce lighting energy consumption. The efforts are frustrated in part by 1) the lack of daylighting availability data, i.e., what are the sky luminance characteristics at a particular location over a year's time, 2) the lack of widely accepted simplified design methods, 3) the lack of widely accepted methods to assess annual energy savings, and 4) uncertainty in the integration of conventional lighting system design with daylighting practice. These issues were addressed by three related activities at LBL. A comprehensive literature search and review of existing data and design methods was completed. An attempt is underway to correlate solar radiation data with illumination values. If this is successful, solar data accumulated at numerous stations would become available for use in daylighting design and assessment. Simultaneous readings of illumination and solar radiation will be taken atop the Pacific Gas & Electric Building in San Francisco to validate analytically derived relationships. Finally, a very comprehensive set of experiments was planned to test various switching control strategies and hardware designs, using the dimmable high frequency ballast experiment in San Francisco. This is discussed in more detail in the section which describes the solid state ballast program.

Beamed Sunlight Project

Conventional daylighting techniques which rely on incident diffuse light are of limited usefulness more than ten or fifteen feet from an exterior wall. Direct sunlight represents a collimated, intense source of high quality light which can be controlled and redirected to interior spaces deep inside a room. This project, undertaken with the assistance of the University of California at Berkeley Department of Architecture, has focussed on the development of sunlighting control devices, to be mounted on the upper portion of windows, which are designed to reflect beam sunlight to a diffusely reflecting ceiling surface deep within a room. Several fixed and moveable devices have been designed and built, both as prototype and full size models. A test apparatus has been designed and built to model the performance of several scale model prototypes and the full size device will be installed in Building 90 at LBL to assess its performance. A survey of a typical office block in downtown San Francisco was completed and preliminary results indicate that there may be very few opportunities to retrofit such devices in existing buildings. Based on current testing, the most promising prototype will be developed in 1978 to the stage where an assessment can be made of its marketability and cost/benefit performance.

High Frequency, Solid State Fluorescent Ballast Program

Fluorescent lighting systems are the dominant form of lighting in the commercial and industrial sectors. A ballast is required in most fluorescent fixtures to first start the lamp, and then regulate current and voltage to maintain light output. Conventional ballasts, which drive the lamps at line frequency of 60 cycles, typically consume 20% of the total lighting system power. Solid state electronic ballasts have been shown to improve system efficiency by 1) reducing ballast losses, and 2) increasing lamp efficacy by driving the lamp at higher frequencies, 20,000-30,000 cycles. High frequency ballasts have been used in space vehicles, in emergency lighting systems and other DC driven applications. In order to be used in AC circuits in buildings, they must have long life, no adverse effect on lamp life, acceptable power factor and low RF noise. Finally, these capabilities must be provided at a price that is cost effective to the building owner.

A development and demonstration program was initiated in 1977. Two subcontractors were selected to complete prototype development of two ballasts with differing capabilities. Ballasts produced by Iota Engineering Inc., were tested by an independent test laboratory and showed efficiency improvements of 20%-30% compared to conventional units. Their design is a low cost approach intended to produce paybacks of the incremental first cost in one to three years, depending upon light output level and energy costs. A ballast developed by Stevens Luminoptics, Inc., is continuously dimmable by manual or automatic means but is somewhat more complex and costly. These units will be delivered for test and evaluation in early 1978.

The true test of the viability of these products is not their performance on a laboraotry

bench but rather in a typical office environment where the unit must survive a variety of thermal and electrical stresses. Our commercialization strategy is based on a demonstration of these units which will be credible to the architectural and engineering design community which ultimately must accept and specify them. A very comprehensive and heavily instrumented demonstration has been planned utilizing solid state ballast retrofits on three floors of the Pacific Gas & Electric headquarters building in downtown San Francisco. An instrumentation system was designed, built and will be installed in early 1978 to monitor all electrical and thermal parameters of interest (approximately 60 channels of data). In addition, eight roof mounted sensors will report solar radiation and illumination levels as part of related daylighting experiments.

This demonstration will provide an opportunity to assess ballast reliability and potential effects on lamp life. A parallel effort is underway at LBL, in conjunction with the fluorescent lamp manufacturers, to assess impact on lamp life. A complete lamp life test capability (aging racks, integrating sphere and associated electrical and photometric measurement capabilities) is under construction at LBL and testing will be initiated in early 1978. A variety of related ballast commercialization activities were conducted. A study was completed of the chronology of developments efforts of high frequency fluorescent lighting systems, a history which spans thirty years. The market potential, from the point of view of both fixture manufacturers and ballast manufacturers, was explored. Power semiconductors are essential elements in the solid state ballast and discussions with manufacturers of state-of-the-art devices were continued. In two to five years, we expect to see integrated circuits and hybrid chips replacing the discrete component devices under development now. We have begun our examination of the impact of these trends on product cost and performance. Finally, we have played a crucial role as a credible source of information concerning ballast development to potential users and developers of this energy saving device.

Other Lighting Activities

Polarized lighting panels have been promoted as a product that provides good visibility with reduced energy consumption when compared to standard non-polarized lenses on light fixtures. A very exhaustive study of published research was undertaken to determine the utility of the panels in a variety of lighting design situations. The tentative conclusion reached was that when used as a direct replacement for a standard fixture lens, the polarized panels do provide greater visibility for most tasks and thus provide opportunities for reduced power output and energy savings.

Fluorescent lighting has never made a very deep penetration into residential applications for economic and aesthetic reasons, and in the past units were not available as replacements for a wide variety of common lamps and fixtures. In the last two years, screw-in fluorescent adapters utilizing small circular lamps have appeared on the market and expanded the range of consumer options. Although their initial cost is considerably higher than incandescent bulbs, because of their long life and improved efficiency it can be shown that they will frequently be more cost effective on a life cycle cost basis. A document has been prepared for consumers containing comparative life cycle cost data to allow them to make intelligent purchasing decisions.

PLANNED ACTIVITIES FOR 1978

Planning was initiated in late 1977 to extend lighting program activities into three new areas:

1) High intensity discharge (HID) lighting systems represent a fast growing sector of the lighting market for both indoor and outdoor applications. All HID systems require ballasts and some appear to offer opportunities for electronics ballast operation which would result in improved energy efficiency and other operational advantages.

2) Switching and control hardware and strategies for lighting systems offer substantial opportunities for both immediate and longer term savings. Development and demonstration of approaches offering improved energy efficiency will be supported.

3) The incandescent bulb is the dominant light source in the residential sector and parts of the commercial sector. Though it is versatile and cheap, it is not very energy efficient. Contract activity will be initiated to support commercialization of one or more energy efficient replacements for incandescent bulbs.

REFERENCES

See review article in the special Berkeley issue Vol. 1. No. 1 of the Journal "Energy and Buildings".

CONSERVATION EDUCATION

C. Blumstein, P. Rowe, L. Schipper, W. Wilms and C. York

INTRODUCTION

The Conservation Education Program of the Lawrence Berkeley Laboratory (LBL) was established in the summer of 1977 to communicate the results of the research and development program in Energy Conservation to those who can utilize and apply those results. When a new technology or idea has been developed, the first step in transferring it into a commonly accepted practice is to disseminate information about it to appropriate audiences. The way in which the new technology works in the field and its subsequent improvements require additional information flow between the developers, the user, potential users and the general public. In the area of energy conservation, when common practice in the use of existing equipment can be changed to produce energy savings, the flow of information is especially important.

It is the purpose of the Conservation Education program to coordinate and expedite this information flow.

The program is organized according to the specific audience to whom the information is directed. In addition to the set of audience-directed programs, there is an analysis program which correlates and generates new information needed for dissemination by the other programs.

PROGRAM ORGANIZATION

1. Teachers' Program

There is a tried and true approach to information transfer which employs the simple device of inducing teachers in the school system to include new ideas and material in their courses. There is an immediate multiplicative factor in the number of people who are aware of the new information when this is done. This program will be divided into several project levels, not only to match the formal structure of the country's educational institutions, but also to reflect the differences in technical detail which the information must contain in order to be communicated to the various audiences.

A summer school for community college faculty has been planned for 1978.

A project to develop "Energy Conservation Strategies on Community College Campuses" has begun.

2. Public Utilities' Customers Program (in collaboration with Pacific Gas and Electric Co.)

Both the '500' Homes Demonstration Project and the Community College Project are collaborative programs with local public utilities.

3. Professional and Skilled Workers Program - Licensure Project

An attempt to modify the state licensing requirements for architects, contractors, accountants, etc. by introducing questions on energy conservation into licensing exams has been successfully started. W. Wilms of UCLA is in charge of this project, which has been supported by the California Energy Commission. The first phase of the project has been completed and the following licensing boards are actively engaged in modifying their examinations to include appropriate energy conservation measures: Accountants, Architects, Contractors, Engineers, Landscape Architects, and Structural Pest Controllers.

4. Television Project

In collaboration with the LBL Public Information Office, a script for a television film strip has been produced. The long-range objective is to produce a pilot series of public service announcements on energy conservation. Louie Robinson has written the script, and Jim Halverson will collaborate in the filming and production.

5. Analysis Program

This part of the program is devoted to special studies needed both to evaluate various conservation education strategies and to analyze energy conservation problems which may require improved educational programs as part of their solution.

Manpower for Energy Conservation. This study, a collaborative effort between LBL and W. Wilms at UCLA, will assess the need for training and retraining professionals and skilled laborers to carry out proposed conservation measures. It will, in a sense, provide a "marketing study" for the Teachers Program, above, to focus the classroom training on the correct audiences in order to upgrade and modify their skills. The work has been planned in 1977 and will be concluded during the summer of 1978.

Overcoming Institutional Barriers to Energy Conservation. Many of the problems associated with increasing the efficiency of energy use are institutional rather than technical. Examples of such problems are: obsolete building codes, lack of methods for re-training already skilled workers in new methods, and misallocation of conservation's costs and benefits (builders vs. buyers, landlords vs. tenants, etc.) While the literature on energy policy is filled with references to such problems, there has been surprisingly little systematic work in this area.

This project, sponsored by the U.S. Council on Environmental Quality, is making a systematic examination of institutional barriers to energy

conservation with the aim of contributing to the development of methods for formulating conservation policy. The initial stage of the project has been devoted to the preparation of a bibliography by E. Krieg. Future efforts in the project will be devoted to an analysis of issues which are especially important to understanding the nature of barriers to energy conservation. Special attention will be paid to problems which might be resolved by improved educational programs. The project team includes C. Blumstein, E. Krieg, L. J. Schipper, and C. York.

LONG-RANGE BUILDING AND APPLIANCE STANDARDS

P. P. Craig, D. B. Goldstein, A. J. Lichtenberg, and A. H. Rosenfeld

We have been stressing the need for a comprehensive approach to saving energy in buildings. To illustrate this approach, we mention a recent study supported by the California Policy Seminar. Entitled "Saving Half of California's Energy and Peak Power in Buildings and Appliances via Long-Range Standards and Other Legislation," the study concludes that savings in space heating can be implemented by upgrading existing California building standards and "sweetening" them with incentives. We would then reduce energy for space heating of homes to less than what is presently required for hot water (270 therms) or consumed by the electric utility to power the refrigerator-freezers in the home (210 therms[1]). Another opportunity for saving energy in the home is increasing the efficiency of refrigerators. Figure 1 is taken from the Policy Seminar paper, and shows that it is possible to reduce refrigerator energy use by one third (from an average of 150 to 100 kWh/mo.) just by comparison shopping. A final gain (from 100 to 50 kWh/mo) will require research, development, and retooling by the manufacturers. According to a survey by A. D. Little,[2] this will add only $50 to the retail cost. Table 1 shows the cummulative peak power savings attributable to eventual "saturation," through normal attrition and replacement with the new optimized refrigerators, would save 2500 MW statewide. This is the reliable output of three 1000 MW power plants, which now cost $1 billion each. But the cost of the 16 million improved appliances is only $750 million! This is another example of the dramatic cost-effectiveness of energy conservation.

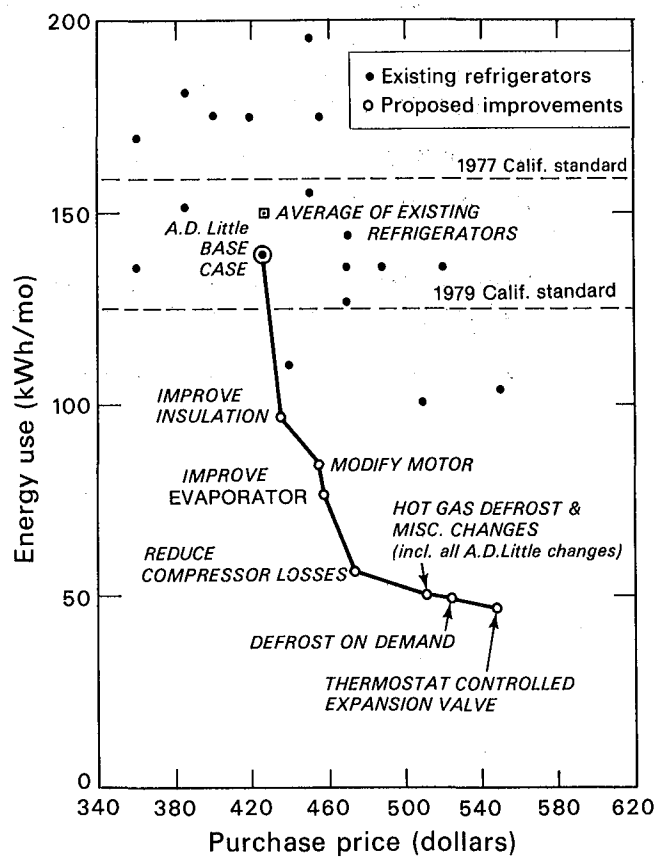

Fig. 1. Energy use vs purchase price for a number of existing and proposed refrigerators. The closed circles in the upper half of the figure represent 16.0-17.5 cu. ft. top-freezer, frost-free refrigerators sold in California in 1976. The open circles in the lower half represent proposed redesigned refrigerators. California standards for maximum energy use allowable for refrigerators of this type shown. (XBL 7712-11464)

FOOTNOTES

1. The average refrigerator-freezer uses 1,600 kWh/year, and there are 1.2 units per household. If the heat rate of the powerplants supplying electricity is taken to be 11,000 Btu/kWh, then the resource energy required is: (1600 kWh/year) x (11,000 Btu/kWh) x (1 therm/10^5 Btu) x (1.2 units/household).

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2. "Conservation Options in Residential Energy Use: Studies Using the Computer Program Twozone", LBL 5271, August 1977.

3. "Saving Half of California's Energy and Peak Power in Buildings and Appliances via Long-Range Standards and other Legislation", California Policy Seminar, January 1978.

Table 1. Peak power savings in California resulting from improvements in refrigerator efficiency, after twenty years of normal replacement.

Action Taken	Statewide Power Savings Resulting From Given Action, MW	Cumulative Savings, MW
1. Chose most efficient model presently on the market	1000	1000
2. Redesign for optimum efficiency	1200	2200
3. Optimize freezer design	300	2500

(Note that the California Energy Commission 1979 Standards will result in statewide power savings after twenty years of 600 MW)

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