Summary Report: The BEPS Redesign of 168 Commercial Buildings

J. L. Stoops
J. J. Deringer
S. Moreno
H. P. Misuriello

May 1984

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America
Available from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

NTIS Price Codes
Microfiche A01

Printed Copy

Pages	Price Codes
001-025	A02
026-050	A03
051-075	A04
076-100	A05
101-125	A06
126-150	A07
151-175	A08
176-200	A09
201-225	A010
226-250	A011
251-275	A012
276-300	A013

SUMMARY REPORT:
THE BEPS REDESIGN OF 168
COMMERCIAL BUILDINGS

May 1984

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

100-2113
DC-324

LIBRARY, BUREAU OF
THE DEPT. OF JUSTICE
COMMUNIST PARTY, U.S.A.

May 1958

Received from
Law Library, Department of Justice
Book Number 100-2113-100

Received from
Library, Department of Justice

CONTENTS

CONTRIBUTIONS	iii
INTRODUCTION	Intro - 1
1. OBJECTIVE	Intro - 1
2. BACKGROUND AND SCOPE	Intro - 4
3. DATA SOURCES	Intro - 7
4. INTERPRETATION OF THE DATA	Intro - 9
5. REPORT ORGANIZATION	Intro - 10
SUMMARY AND CONCLUSIONS	Intro - 11
BUILDING TYPE ANALYSIS: OFFICES	1 - 1
1.1 Energy Characteristics of Office Buildings	1 - 1
1.1.1 General Overview of Issues and Potentials	1 - 2
1.1.2 Usage Profile	1 - 2
1.2 Building Sample Issues	1 - 3
1.3 Analysis of Redesign Strategies	1 - 4
BUILDING TYPE ANALYSIS: RETAIL	2 - 1
2.1 Energy Characteristics of Retail Buildings	2 - 1
2.1.1 General Overview of Issues and Potentials	2 - 1
2.1.2 Usage Profile	2 - 2
2.1.3 Typical End-Use Percentages	2 - 2
2.2 Building Sample Issues	2 - 2
2.3 Analysis of Redesign Strategies	2 - 3
2.4 Fulfillment of the Technical Potential	2 - 4
BUILDING TYPE ANALYSIS: RESIDENTIAL HOUSEKEEPING AND NON-HOUSEKEEPING BUILDINGS	3 - 1

3.1	Residential Characteristics	3 - 1
3.2	Integration of Passive Solar Strategies	3 - 3
3.3	Hotel/Motel Strategies	3 - 4
BUILDING TYPE ANALYSIS: CLINICS AND HOSPITALS		4 - 1
4.1	Health Design Criteria	4 - 1
4.1.1	Lighting Requirements	4 - 1
4.1.2	HVAC Requirements	4 - 2
4.2	Redesign Strategies	4 - 5
4.2.1	Patient Areas	4 - 5
4.2.2	Support Areas	4 - 6
4.2.3	Ancillary Functions	4 - 6
4.2.4	HVAC Zone	4 - 7
4.2.5	Plant and Heat Recovery	4 - 7
BUILDING TYPE ANALYSIS: ELEMENTARY AND SECONDARY SCHOOLS		5 - 1
5.1	Berming	5 - 1
5.2	Natural Lighting	5 - 2
BUILDING TYPE ANALYSIS: STORAGE AND ASSEMBLY BUILDINGS		6 - 1
6.1	Storage Buildings	6 - 1
6.1.1	Building Characteristics	6 - 1
6.1.2	Energy End-Uses	6 - 2
6.1.3	Redesign Strategies	6 - 3
6.2	Assembly Buildings	6 - 4
6.2.1	Building Characteristics	6 - 5
6.2.2	Energy End-Uses	6 - 6
6.2.3	Redesign Strategies	6 - 6

CONTRIBUTIONS

A number of individuals and organizations have contributed to the development of this research report and to the Progressive Architecture (PA) Magazine energy conscious design article series which conveyed its results. Major organizations that participated in the original BEPS research are acknowledged in the Introductory P/A article on Phase I and Phase II in this report.

Principal Researchers:

Harry P. Misuriello, Principal
W. S. Fleming & Associates, Inc.
Joseph J. Deringer, President
Santiago Moreno, Associate
Gilford, Deringer and Company

Editorial and Graphics:

Richard Rush, PA article series editor (now with the AIA);
Sue Newberry and David Scott, article layout and graphics
preparation at PA.

Researchers:

James Binkley, Chief
Ted Kurkowski, Program Manager
Commercial Building Systems Analysis
Architectural and Engineering Systems Branch
Department of Energy
John Stoops, Project Manager
Ray Reilly, Program Manager
Stan Pansky, Project Architect
Battelle/Pacific Northwest Laboratory
John H. Cable, Principal
John Cable and Associates
Richard Menge
Saudi Arabian Parsons, Ltd.
Roger Easley
Consultant to Battelle
Mike Gilford
Richard Meilan
Terry Ann Nyuberg
Gilford, Deringer and Company
Verna D. Hawkins
W. S. Fleming & Associates, Inc.

INTRODUCTION

1. OBJECTIVE

The objective of this report is to present, in usable form, summary data from the Building Energy Performance Standards (BEPS) Phase II commercial buildings energy research conducted in 1978-79. Summary data presented were obtained from two major research efforts:

- the BEPS Phase II Redesign experiment, conducted in 1978
- the related research on ASHRAE Standard 90-75R conducted in 1978-79.

This report is one of several products from a project conducted in 1981-83 to analyze and publish data produced by the earlier 1978-79 research.

In addition to this report, the project conducted in 1981-83 has also produced a series of eight articles in Progressive Architecture magazine during the period April 1982 - April 1983. The article series included an introductory article, six articles discussing specific "commercial" building types, and a concluding article. Copies of the eight articles are included in this report. The contents of the eight articles are summarized below:

A BASELINE FOR ENERGY DESIGN (April, 1982) introduces the series, briefly describes the principal individual elements of the research, and presents overall results and observations.

ENERGY DESIGN OFFICE BUILDINGS (June, 1982) focuses on the major redesign strategies used in small and large offices to address the characteristic concerns of diurnal heating and cooling and dynamic solar gains.

ENERGY FOR SALES (August, 1982) emphasizes effective redesign strategies for retail buildings and discusses interior systems, such as lighting and HVAC, in characteristic internally loaded steady-state operation.

DWELLING WITH ENERGY (October, 1982) concentrates on energy strategies for high- and low-rise multifamily dwellings and reveals that solar control and architectural design features play a surprisingly influential role in energy use.

BED, BOARD AND BTU'S (December, 1982) examines the diversity of nursing homes, motels and hotels as a continuum, with increasingly complex relationships between sleeping rooms and service areas.

Relocation of spaces, outside air reductions, and shell tightening are a few of the strategies employed.

ENERGY TO RECOVER (February, 1983) highlighted HVAC and heat recovery strategies that were key in dramatically reducing hospital energy use without compromising health care criteria.

ENERGY: A CLASS BY ITSELF (March, 1983) concludes that the energy importance of intermittent usage patterns inherent in elementary and secondary schools resulted in design decisions that enhanced the use of natural lighting while minimizing conductive gains and losses. Mechanical system controls for idle spaces were also important contributors to higher-than-average energy savings.

168 PROOF? (April, 1983) arrives at a number of conclusions regarding targets of opportunity in energy-conscious design. Strategy patterns observed in the redesign experiment led to a new three-part categorization of building types in the commercial and multifamily residential sectors.

Overview of the BEPS Research

The BEPS 1978-79 Phase II Commercial Building Redesign Building experiment was part of a multi-year research effort in support of proposed federal standards for energy performance for all new buildings. Two national samples produced large quantities of data on the energy behavior of new buildings constructed in the mid-1970's.

- Phase I (1977): a baseline sample of over 180 building designs, with about 100 data points per building. Annual energy consumption was estimated by computer simulation for over 1660 building designs.
- Phase II (1978): a subset of 168 buildings from the Phase I sample (except for the multifamily low-rise sample). Detailed annual energy analyses were done both for the buildings as originally designed and as redesigned for energy conservation, using data supplied by the building design teams.

Large amounts of data regarding building energy use were generated during the course of this research. For example, the computer printouts alone for data inputs and for summary energy results, are well in excess of 100,000 pages. These data are a valuable source of information for design professionals, especially the data about the redesign strategies used during the Phase II redesign experiment. According to the computer simulation

results, these strategies resulted in a projected average 40% annual energy consumption reduction from the original building designs.

Immediately following the research effort, the bulk of the available resources were focused on the task of producing a federal energy regulation for new buildings. A Notice of Proposed Rule-making was published by the Department of Energy in November 1979 (DOE BEPS NOPR). In the NOPR, DOE proposed energy budgets or targets for sixteen commercial building types, and for residential building types.

Analysis of the BEPS Phase II Data and Design Strategies

Finally, in 1981, this current effort to analyze the efficacy of the design strategies (and much of the data) used in the 1978-79 research, and to publish summary results was begun. The effort has produced the series of magazine articles and this report. Because the articles have been the major vehicle for summarizing the research results, and have been included in this report, relatively little additional text has been included in this report over and above the text in the articles.

The bulk of this report consists of data tabulations of key energy parameters for the 168 sample buildings, which were tabulated from computer-stored files of the 1978-79 data. The data have been grouped by building type. Two kinds of tabulations are included:

- numerical tabulations generated by a computer program that extracted information from the computer-stored data base for the 168 sample buildings.
- graphic presentations of the computer-generated data, plus data extracted from other sources.

The intent here is to provide a single data compendium of key energy-related factors from the 1978 redesign experiment and the associated 1978-1979 ASHRAE Standard 90-75R research.

This report also supplements the information in the articles in an effort to further clarify technical issues and to present conclusions for which there was not space in the magazine articles. Thus, for some building types, additional analysis, comments, and data tabulations are included here that could not be included in the articles because space was limited. These additional analysis items are not consistent across building types because both the energy conservation opportunities and the design strategies applied by the building designers varied considerably by building type.

These differences, in turn, guided the direction of the analysis and reporting of the summary research results. One intent of this analysis has been to describe in as much detail as possible which design strategies contributed most to the significant projected energy reductions in the 1979 Redesign experiment. However, we have been limited to making only qualitative assessments of design strategy impacts, using professional judgment in analyzing the voluminous data. Two factors severely limit the development of more quantitative assessments of individual redesign strategies:

1. The focus of the 1978-79 research was the whole building. The objective of that research was to determine the overall impact on annual energy performance of new building designs resulting from complete redesigns of original buildings by their architects and engineers of record, or of sets of changes to building features to meet the Standard 90-75R requirements. Separate analyses of specific design strategies were not part of the research objectives, and were not made.
2. Retained results from the computer energy analyses included only the energy results; data on loads from spaces on the systems were not retained.

Because of these two data limitations, quantitative assessment of impacts of individual strategies from the 1978-79 BEPS data is very limited. Also, the limited (i.e., national) sample size per building type precluded evaluations of regional variations in design strategies caused by variations in climate, construction practices, and fuel availability and pricing. However, this report, and the series of articles, contain a number of useful qualitative observations about the application of various design strategies by building type and guidance about the usefulness of particular strategies given the energy conservation opportunities within building types.

2. BACKGROUND AND SCOPE

This report, and the research it describes, should be viewed in the context of a much larger body of research. To reference work accomplished in the late 70s and early 80s, refer to the extensive BEPS bibliography. More recent research has concentrated on analyzing impacts of specific design strategies for conserving energy. For example, three recent DOE-funded research efforts now nearing completion will provide more detailed information about the effectiveness of at least some design strategies on some building types. These projects are:

- Analysis of means to upgrade, on a cost-effective basis, ANSI/ASHRAE/IES Standard 90A-80, "Energy Conservation in New Building Design.
- Evaluation of Heating and Cooling Requirements in New Single-Family Residences
- Development of a Small Office Building Handbook: Design for Reducing First Costs and Utility Costs

Building Types

Data for thirteen building types are included in this report. The building types are grouped in the same sequence and combinations as used in the magazine articles. These are:

- small and large offices
- retail: regional malls, department stores, neighborhood centers, strip shopping centers
- residential housekeeping: multifamily high- and low-rise
- residential non-housekeeping: hotels/motels and nursing homes
- clinics and hospitals
- elementary and secondary schools
- warehouses

Energy design strategies corresponding to characteristic building type energy concerns are identified within each building type and in certain subtypes. Both actual redesign trends and potentials are specifically related to each type. Predominant strategies analyzed cover major energy-related aspects of building design:

- building program
- form and envelope
- lighting
- HVAC

Patterns in the application of design strategies cutting across building types are also identified and related to building characteristics.

Special Cases In analyzing and describing several of the building types, exceptions in the manner in which the analysis has been performed have been required. These exceptions are discussed briefly below.

Assembly buildings. The 1979 DOE NOPR mentioned above disaggregated the assembly building type into three subtypes (community centers, gymnasiums, and theater/auditoriums). This disaggregation was accomplished through a statistical analysis of the combined Phase I and Phase II data bases. The larger size of the Phase I data base (some 1660 building designs) permitted analysis of enough buildings of each subtype within the assembly building type for the disaggregation to be accomplished.

We have not disaggregated the assembly building category in this report. We have been analyzing only the smaller Phase II data base. In this data base, there are not enough sample buildings in each subtype within the assembly building category to permit meaningful analysis of the subtypes separately.

Restaurant and Fast Food. The original BEPS redesign effort for commercial buildings included restaurants and fast food establishments. Energy results for these two building categories were distorted by the deletion of all "process" energy from the energy analysis. Since such "process" energy for kitchen equipment and kitchen exhaust makeup air is the overwhelming energy use in restaurant and fast food establishments (constituting some 60% to 80% of the total energy use), the results for those two building types were disregarded both in the DOE NOPR of 1979 and in the subsequent analysis presented here.

Since our analysis did not include the 16 restaurant and fast food sample buildings, we have actually analyzed the data for only 152 of the 168 original sample buildings. We refer to "168" buildings because many people familiar with the BEPS research recognize this number. Likewise, the results of the analysis of ASHRAE Standard 90-75R include 125 of the 168 buildings (excluded, in addition to restaurants and fast food, were multifamily high-rise and low-rise).

Partial Analyses. The series of articles in Progressive Architecture magazine did not include articles on either assembly buildings or warehouses. We have included the data tabulations for these two building types. However, since an in-depth analysis was done only for the building types

featured in the articles, the data for assembly buildings and warehouses were not analyzed to as great an extent.

3. DATA SOURCES

A variety of sources was used to gain insight into the energy conserving features of the 168-building redesign effort. Vast amounts of information had to be painstakingly extracted, consolidated, formatted and tabulated for analysis and review. The data sources used to generate the data in this report and to perform the analyses that produced the article series in Progressive Architecture included the many reports in computer-stored data files produced during the Phase II commercial building redesign effort. From the large body of data produced during this effort, the major sources of information for this analysis included:

- input data for energy analysis and computer results for each of the 168 buildings. At the end of Phase II, separate volumes were prepared for each building in the research effort. These volumes included 1) the data input forms prepared by the design teams for each original and redesigned building; 2) computer-based, date-checking output that verified the ranges of input data items; and 3) summary computer results for the energy analysis of the original and the redesign building. Note that analyses on ASHRAE 90-75 conducted during this period were considered to be incomplete.
- drawings and specifications for both the original and redesign buildings. The design teams submitted copies of drawings for the original buildings as part of the Phase II design effort. Schematic design drawings were also submitted. In most instances this material was placed on microfilm by the AIA Research Corporation. However, when our analysis began, some of this material had been lost or mislaid. Only 60% of such drawings or microfiche were available. The drawings that were available represented a very valuable source of data for analysis.
- computer-stored data on building energy characteristics and results. As part of the Phase II energy analysis, the energy-related data supplied by the design teams on their data input forms were stored on computer disk files. These data have been stored at Syska and Hennessey Information Systems (SHIS) in New York City. Copies of the data base for the 168 buildings were transmitted with file documentation to PNL. These data tapes represent a potentially valuable source of information. A computer

program to extract key building parameters from the Phase II data base was developed. The program was executed at SHIS where the Phase II data base is maintained on a DEC 1170 computer system.

In addition to the data generated during Phase II there were several followup analyses that were conducted in 1979 and 1980. Extensive use was made of relevant data from two key studies:

- Analysis of ASHRAE Standard 90-75R. This analysis was begun during Phase II in 1978. However, the results produced at that time were not considered adequately representative of the impacts of Standard 90-75R. Consequently, in 1979 and 1980, more detailed work was performed on 125 of the 168 buildings. In 1980, the AIA Research Corporation published the results for the Department of Energy in a report entitled "Analysis of ASHRAE 90-75", AIA/RC, 1980. This report is in two volumes. Volume I summarizes the analysis and Volume II contains numerous data tabulations. The computer runs for this analysis were conducted on the ACCESS computer program from the building data contained in the Phase II disk-stored computer files. (These data tapes have also been transmitted to PNL for public use.) We have drawn on the results of this report and on the output of the computer-stored data in representing the analysis results for the impacts of Standard 90-75R.
- Life Cycle Cost Study of Commercial Buildings: analysis of three office buildings. Because the Phase II analysis did not examine in depth that life cycle cost implications of the energy conservation strategies, three buildings from the Phase II sample were studied in greater detail during 1979 and 1980. The results of this were also incorporated in the analysis "Energy Performance Standards for New Buildings. Life Cycle Cost Study of Commercial Buildings" by AIA/RC with Hanscomb Associates, Inc. and Syska & Hennessy Engineers, Inc.

Other significant reports used include:

- Analysis of Data Anomalies. Further Analysis of Phase II Buildings. AIA/RC, March 1980.
- Phase II Report for the Development of Energy Performance Standards for New Buildings. Appendix D, Energy Conscious Designs. U.S. Department of Housing and Urban Development, January 1979

For additional relevant data sources please refer to the bibliography contained in Appendix II of this report.

4. INTERPRETATION OF THE DATA

The data presented in this report are subject to limitations in three major areas:

- technical limitations with regard to the energy simulation program used
- incomplete reporting of data
- data extraction anomalies

These shortcomings are noted in the article series where they are pertinent to the analysis of a particular building type.

Technical Limitations

The technical limitations of the energy program used at the time prevented the simulation of strategies such as daylighting, deadband and any form of passive thermal storage. Also, data handling errors in the course of the simulation led to a severe underestimation of domestic hot water heating energy for multifamily low- and high-rise buildings, nursing homes, and motels.

Incomplete Reporting of Data

Incomplete reporting of data occurred for the most part in the lighting area. Tenant connected lighting loads were not included in either the stores/shopping centers or the multifamily low- and high-rise categories.

Not analyzing process loads probably distorted end-use results in the case of hospitals and perhaps hotels, where the multiplicity and coincidence of heat sources and demands make this building type a prime candidate for heat recovery strategies. Process loads were not included in the analyses due to an early policy decision to limit the regulatory intent of the standard to space condition loads only. However, the data submitted by the design teams did contain process load data.

Data Extraction Anomalies

An example of such anomalies is that foot-candle values extracted are averages for the total net conditioned area of the building under consideration. These averages are weighted according to lamp types and building zones. Abnormally low values not only

reflect this weighting process, but in a few isolated cases, task lighting illumination levels were not included for the lamp types concerned.

Heating Efficiencies

Values of zero for heating efficiencies are found where there is either an absence of mechanical heating or a heat pump is utilized. The presence of unitary or condenser water loop heat pumps can be confirmed when there is a positive entry in the "HP Heating COP" column on table of figures X.6. The presence of chillers with double-bundle condensers cannot be directly identified. An entry of zero in both the "Chiller Cooling COP" and "HP Heating COP" columns could indicate either the absence of mechanical heating or the presence of a double-bundle condenser.

5. REPORT ORGANIZATION

The introductory article and the concluding article in the series are included in the next section, entitled Summary and Conclusions. These two articles together provide an excellent overview of the material both in the article series and in this report.

Building types are presented in the sequence indicated above. Particular types are analyzed with respect to the most significant energy concerns and potentials that result from the type and mix of functions being served and their usage profiles. The most prevalent redesign trends are identified in terms of the specific strategies used for siting, envelope, lighting and HVAC. Redesign trends are then compared to the actual technical potential of the building type. In each case, the analysis is supported by plots of all key energy parameters and conveniently formatted data on all the energy inputs used to perform the energy simulations for all 168 buildings.

SUMMARY AND CONCLUSIONS

2012-10-10 09:00:00

11-0000

A baseline for energy design

This article serves as an introduction to a series of articles reporting the findings of the largest research effort ever undertaken on building design. A key element of the study was the energy-conscious redesign of 168 commercial and multifamily residential new buildings. The research described in this series has been followed by related studies, currently underway, that are intended to answer additional questions about the energy behavior of such buildings. This effort has been funded by Battelle Pacific Northwest Laboratory under a program sponsored by the Buildings Division of the U.S. Department of Energy.

Contributors: A number of individuals and organizations have contributed to the development of this article. Principal researchers: Joseph J. Deringer, AIA, President, Gilford, Deringer and Company; Harry Misuriello, Principal, W.S. Fleming Associates.

Researchers: John Cable, AIA, Director, Buildings Division, DOE; Richard Menge, RA, Branch Chief, Buildings Division, DOE; James Binkley, AIA, Program Manager, Buildings Division, DOE; John Stoops, Project Manager, and Ray Reiley, Program Manager, Battelle Pacific Northwest Laboratories; Roger Easley, Consultant to Battelle; Santiago Morino, Mike Gilford, PE, and Richard Meilan, PE, with Gilford, Deringer and Company.

Over the past five years, over \$30 million has been spent on research initiated to produce "baseline" data on the energy performance of new buildings and to determine maximum practical levels of potential annual energy conservation for the designs of new buildings. The effort was primarily to develop a data base that did not exist at the time to support the proposed Building Energy Performance Standards (BEPS). Numerous organizations, building designers, and energy experts participated in the research part of the effort. At one point, over 700 persons and more than 350 organizations were actively involved. Literally hundreds of reports have been produced. The computer printouts alone for just the research on the redesign of 168 commercial and multifamily buildings discussed in this series are well over 100,000 pages.

Very little of this enormous research effort has been published in a format useful to the building community. In these articles, an extensive effort is being made to present in a useful format key results from the research. The series of articles will also try to explain what was not learned and will address many unanswered questions.

This particular article provides an introduction to the series, briefly describes principal individual elements of the research, and presents overall results and observations. Future articles in the series will examine design strategies and energy results in more detail for selected building types.

Research effort

The original effort was divided into two main phases (plus follow-on research). The objective of the first phase was to develop "baseline" data about the energy performance of new buildings. The purpose of the second phase was to determine potential levels of energy reductions that could be achieved from this baseline.

In both phases, estimates of annual "design energy performance" were made by calculating the amount of energy a building might use over a year's time. The estimates were of "potential" energy use once a building would be constructed, but using data available during the design stages. The energy analysis included only new building designs, not existing buildings. Separate estimates were made for 16 different major building types, recognizing the strong impacts on energy requirements caused by a building's function and the diversity of such functions in commercial buildings. Designs were selected from 37 cities to examine a range of climatic impacts. Factors that could significantly affect the energy use of a building, but which are not under the control of the building designer, were either normalized (e.g., hours of operation) or eliminated from consideration (e.g., "process" energy to perform a service or conduct a business or off-site electric energy conversion losses).

Under the management of The AIA Research Corporation, the first phase of this research in 1977 included the statistical selection and development of an annual energy performance "baseline" for over 1600 buildings designed and built in the mid-1970s. The energy estimates were made from summary building design information supplied voluntarily by architects and engineers.

In the second phase of the research, during 1978, a subset of 168 buildings was statistically selected from the first-phase sample. Annual energy estimates were made for these "original" 168 buildings, this time in great detail. Also, an important experiment was conducted: To determine the possible levels of energy efficiency that could be achieved, these 168 buildings were "re-designed" by their original architect and engineer design teams, who were placed under contract to do the redesigns. To launch the redesign experiment, the design teams participated in a three-day workshop in energy-conscious design concepts and strategies, and received an energy information workbook. At two

subsequent points over a period of months, they presented their work and received a detailed peer review and feedback from energy consultants.

Although the design teams had few constraints on their redesign efforts, they were required to adhere to the building owner's original program requirements, the site, and the general range of the construction budget. They were encouraged to use "passive" techniques, including natural ventilation and daylighting. Active solar systems were not permitted unless included in the original designs (there were four).

The designers completed computer input forms for both the original buildings and the energy-conscious redesigns. This information was analyzed by the research team using a sophisticated energy analysis computer program (a method similar to that used in the recent P/A "Energy Analysis" series) so that the various design energy performances could be compared in a controlled and consistent manner. The comparison focused on the physical characteristics and design strategies of the buildings (rather than on variations in hours of operations, which can radically impact energy performance). Standard operating conditions were developed for each space function (e.g., classroom, gym, cafeteria) within a building type by averaging the estimated hours of operation supplied by the design teams.

The redesigns were designs completed essentially only through the schematic phase, but with sufficient additional data to conduct a detailed energy analysis. The redesign exercise was therefore a large experiment. One could speculate that significant energy reductions were possible through the redesign, but it was not known at the outset whether the efforts would result in a 5 percent or a 50 percent energy reduction. Also, it was not known if such a large number of designers, many of whom were unfamiliar with computer energy analysis, could prepare meaningful data processing input.

Summary estimates of first-cost differences between original and redesign were submitted by the designers as part of the exercise. At the end of this phase, on the average, the redesigners reduced energy use by 38 percent and increased first cost by less than 5 percent from the

FIGURE 1 ENERGY END USE PERCENTAGES

FIGURE 2 ENERGY PERFORMANCE RANGES

Figure 1 Bar sections indicate original and redesign energy and use percentages for each building type. **Figure 2:** Bars show original and redesigned building energy performance ranges for Kansas City, to represent an average or national climate condition. The center line in each bar indicates the average (actually the 50th percentile) for each range. The ranges shown exclude the extreme 20 percent at each end.

original buildings. Figure 2 indicates example ranges of annual energy performance by building type for Kansas City. The cost effectiveness of the redesigns could not be adequately assessed from the redesign data, and a follow-up initial life-cycle cost analysis was conducted in 1979-1980 for three typical office buildings from the sample. Similar research is now under development for other commercial building types.

Targets of opportunity

A key factor in energy-conserving design is an understanding of how energy flows in buildings. One aid in identifying broad targets of opportunity for energy conservation is to examine the amount of energy used for building energy functions or "end uses." A familiarity with energy end uses and their relationships within a building type can provide useful guidelines for focusing the design effort where it might have most significant impact.

Energy "end uses" refers to those major building functions or services for which energy may be used. Typical major energy end uses in commercial buildings as presented here are: space heating and cooling; HVAC fans and pumps; lighting; service water heating; vertical transportation; and exhaust fans. Energy is also used for building "processes" to produce a product or provide a specialized service: e.g., computers; laboratory equipment; or laundries. While data were collected on process energy, they were not included in the energy analyses and will not be addressed here.

Figure 1 shows the overall average for percent of annual energy used for five major end uses in the original buildings

and in the redesigns. As indicated, the percent of total energy use varies considerably by building type. For example, energy for space heating accounts for over 75 percent of the total for the original warehouses studied, but less than 30 percent for original large or small offices. Likewise, energy for lighting accounted for less than 15 percent of the total energy for hospitals, but close to 35 percent of the total energy for stores and shopping centers.

In the redesigns, major reductions in lighting levels occurred. Yet in the redesigns of virtually every building type, lighting increased as a percent of total energy use. This suggests that lighting tends to become a more important energy consideration as commercial buildings become more energy efficient.

The percentages in Figure 1 indicate the national averages for energy use in the buildings of each type. These summary charts indicate general patterns by building type, but do not necessarily show variations that can occur within a building type depending on regional influences such as climate, local construction techniques, material usage, design practices, and fuel availability and cost. Such factors define important constraints under which designers operate.

Within a given building type, the heating and cooling energy end uses were found to be particularly sensitive to regional variations, whereas other end uses such as service water heating and lighting are much more sensitive to patterns of building occupancy, functions, and mix of building functions and are influenced very little by climate factors.

Service water heating is a major component of the "other" end use shown in Figures 1, 2, and 3. The "other" category also includes vertical transportation and exhaust fans. The reader is cautioned that these data underestimate

the extent of the often substantial energy used for heating service water in hotels, motels, and hospitals for such uses as laundry and food storage and preparation, because of the decision to exclude such "process" loads from the research analysis.

Results of the redesign process

The redesign experiment produced significant reductions in projected energy use. The average unweighted reduction for all redesigned buildings was 38 percent. Figure 3 shows the average results of the redesign process for the sample buildings in each building type.

One important factor was the amount of variation in the results. The average decrease varied considerably by building type. It was greatest for warehouses (55 percent), and for small offices (50 percent), and smallest (26 percent) for hotels and high-rise residential.

The range of annual energy usage for most redesigned building types was smaller than the usage range estimated for the original buildings. This is illustrated in Figure 2, and suggests that carefully selected design strategies can temper overall regional influences on both energy use and percentages of end use.

In the redesign exercise, certain building energy end uses were reduced by significantly larger absolute amounts than others. This was directly related to their predominance as end uses in the original buildings. Heating energy was reduced more than the other end uses. Especially for "skin," or external-load-dominated building types, reductions in heating energy were significant, while reductions in cooling energy were small. Likewise, building types that tend to be predominantly internal-load dominated, such as shopping centers, offices,

FIGURE 3 AVERAGE END USES FOR TYPICAL BUILDING TYPES

and stores, achieved the greatest reductions in cooling energy.

Limits of the energy analysis method: A reasonably comprehensive energy analysis computer program was used to estimate the energy use of the building designs. Like most such energy analysis programs, then and now, the program was capable of analyzing many of the design strategies, but not all.

For example, two strategies used in many redesigns had significant potential energy savings that could not be evaluated—daylighting and “deadband” thermostatic controls. It is the authors’ opinion that if the impacts of these two additional strategies had been estimated, the average percent energy reductions of the redesigns would have been closer to 45 percent instead of the 38 percent reported. (Additional discussion of limitations of energy analysis tools is contained in Energy Analysis overview articles in April 1980 and 1981 in P/A.)

Application of the component requirements of ASHRAE 90-75R to the original buildings also produced significant energy reductions. Exact conformance to the ASHRAE 90-75R minimum component requirements using the formal “Upgrade/Downgrade” approach resulted in a 22 percent reduction from the original buildings. Results of this approach are shown for 12 building types in Figure 3. The middle bars for multifamily high-rise and low-rise residences show the impacts of HUD MPS. The second “Upgrade Only” approach resulted in a 34 percent reduction from the original buildings.

What was learned from the research: Significant energy reductions are possible from design practice. Further, such reductions can be accomplished with a relatively small increase in average first cost. In some cases, first costs decreased.

For example, reduced heat gain from lighting permitted reductions in ventilation rates and in installed cooling capacities. While lighting system costs may have increased, these were more than offset by reduced costs for the installed cooling equipment. In three office buildings examined in detail, total energy was reduced about 30 percent and first costs were reduced as well.

The research provided estimates of the energy behavior for a number of building types, as well as some estimate of the impact of climate on each type. Also, from the results from the sample buildings, new building annual energy target ranges were developed for 16 building types in some 78 cities by using a statistical estimating procedure. Example results for one city are shown in Figure 2.

What was not learned: More correlation between design estimates of energy and actual consumption is needed. Extensive comparisons were not made between the design estimates of the original buildings and their actual consumption.

It is not known how much more conserving design practice is today, compared with when this study was done. Similar broad surveys of design practice have not been conducted since. A more recent summary analysis of characteristics of an existing sample of some 400 buildings, however, concluded that only minor increases have occurred in the use of energy conservation items.

Additional information is needed on cost effectiveness of energy-conscious design. In short, did the redesigns go too far or not far enough. Preliminary results of more recent research suggest that energy use levels at or below the redesign levels may be cost-effective from several economic perspectives. This work, however, is not yet complete.

Little effort was made in the research

Figure 3 This figure shows the average energy use for each building type for three conditions: the original design, the ASHRAE Standard 90-75, and the redesign. Total annual energy and end uses are expressed in thousands of Btu/sq ft/yr for heating, cooling, fans, lighting, and other end uses, including service water, heating, elevators, escalators, and exhaust fans.

ASHRAE 90-75R and HUD MPS

Another major part of the Phase 2 research effort was the application to the original buildings of the minimum component requirements of current standards. The objective here was to determine the annual energy performance impacts of the standards on a large set of actual building designs. HUD Minimum Property Standards (HUD MPS) were applied to multifamily high-rise and low-rise residences. ASHRAE Standard 90-75R component requirements were applied to all other commercial building types.

This part of the research was conducted very differently from the redesign experiment. The design teams were not involved in modifying their original buildings to meet the requirements of either standard. Instead, a research team made very detailed interpretations of each of the requirements. The component characteristics of the original buildings were then modified automatically via computer, using a consistent procedure, and new energy estimates were made using the modified data.

For ASHRAE 90-75R, the building components affected were either "upgraded" or "downgraded" to meet the exact minimum requirements. This "Upgrade/Downgrade" approach was thought to provide a "formal" measure of the range of impacts of the minimum requirements of the standards. A second approach to the ASHRAE standard was also conducted. In this approach, those components that failed to comply were "upgraded" to meet the minimum requirements, whereas those components that surpassed the requirements were left unchanged. Neither approach measured the energy impacts of how the standard might be interpreted and applied by a large group of designers. But from the research effort, it became clear that different "reasonable" interpretations of some of the component requirements could produce large differences in the energy results.

The requirements of HUD MPS applied mainly to the thermal transmittance of the building envelope, while ASHRAE 90-75R had minimum requirements for components of the building systems as well. This part of the work was refined and completed in 1980. As a result of that analysis, research is currently underway to examine possible ways to tighten the requirements of the current version, ANSI/ASHRAE 90A-80, on a cost-effective basis.

to isolate those strategies that were most effective in producing the reductions and in examining why the reductions occurred. A major thrust of these articles will be to begin to identify and describe such strategies by building type and region.

Many of these issues and questions are being directly addressed in current research on commercial and multifamily buildings as a consequence of what was learned from the redesign experiment. In the coming series, the authors will try to address some of these questions and possible implications.

The design teams

The research concentrated on the energy behavior of the sample building designs. In retrospect, the redesign experiment also provided an opportunity for examining how the attitudes, skills, experience, and design procedures of the designers impacted energy results. However, very little of this was done. Thus, the following comments about the design teams are qualitative and are derived from observations by the authors and by reviewers of the redesign.

The design teams "came along" with the buildings, which were selected to represent statistically new buildings of each type throughout the nation. As a result, the designers participating in the redesign exercise had a wide spectrum of energy skills and experience. A few of them had solid energy analysis experience. There were also a number of energy novices in the group.

The effort put into the redesigns also varied considerably. Some design teams made only minor modifications to their original buildings. Others developed sophisticated and completely new solutions using a full spectrum of design strategies.

Not all of the redesign attempts succeeded. According to reviewers of the completed redesigns, many designers did not take advantage of obvious conservation opportunities. Nine redesigned buildings (6 percent of the total) "failed" in the sense that the redesigns used more energy than the original buildings. In a number of cases, designers either used strategies that were inappropriate or used potentially effective strategies but misapplied them.

The "failure rate" experienced, however, does not seem to be an isolated consequence of this research experiment. In a recent DOE survey of retrofits of over 220 existing commercial buildings, a similar failure rate was discovered. About 10 percent of the retrofits for over 220 buildings "failed" because the actual metered consumption went up instead of down after the retrofit. In that survey, the major problem seemed to be the misapplication of building operation practices.

OFFICE DAYLIGHTING STRATEGIES

ORIGINAL (Power Density: 2.75 W/sq ft): Single glazed, non-continuous fenestration finish facade—4 lamp wide recessed troffers with flat prismatic lens.

REDESIGN (Power Density: 1.8 W/sq ft): Double glazed continuous windows with heat strengthened tinted glass with thermal-break frame; overhangs and/or fins, depending on exposure; moderate textures and medium dark tones to increase absorbance; 2 lamp parabolic troffers, vented, photocell controlled dimmers.

TASK LIGHTING/LIGHT SHELF OPTION (Power Density: 1.3 W/sq ft): Window band below light shelf—double glazed with thermal break frame; Window band above light shelf—insulating low glare panels of translucent fiberglass; light shelf/overhang; bidirectional venetian blinds control glare and direct light further into space—furniture mounted task lighting; twin-beam parabolic fixtures for general lighting.

The authors feel that the redesign energy results do not necessarily reflect the energy conservation technical potentials that are achievable for each building type. Rather, the results indicate what a cross section of designers can achieve at a point in time, given incentive and a small amount of information, training, and feedback.

The coming series

In the coming months, this series of articles will analyze the design strategies, energy results, and building characteristics for specific building types such as large and small offices, elementary and secondary schools, high- and low-rise residences, and warehouses. The articles will also describe changing patterns in many physical characteristics from the original buildings to the redesigns.

The series will concentrate on those building types with the largest projected construction volumes in coming years. The intent is to present from the research practical information and concepts that might be used by building designers as guidelines to help enrich their energy-conscious design vocabularies.

Throughout the series, feedback is invited and encouraged, including examples of recent energy-conscious design efforts and experiences with applying specific strategies. Observations about including energy considerations early in a building's design stages are particularly sought. It is hoped that sufficient interest will merit presentation of this material in conjunction with one of the articles in the series. □

Design strategies

We present here a few illustrative examples of redesigned buildings and design strategies.

Example 1: Office building in Farmington, Ct. Architects, Russell Gibson von Dohlen; engineers, Quinlan & Giannoni. This redesign reflects the substantial savings possible from a series of relatively standard energy-conscious design strategies. The three-story, 47,000-sq-ft building on a suburban site is for a speculative client. The original building faced the main road and caused the long elevations of the building to face almost east and west. The redesign was reoriented so that the long elevations faced north and south.

The building was made slightly longer and narrower. Glazing was totally eliminated on the east and west short elevations for better solar control as well as reduced cost. Double glazing replaced single glazing, and external shading on the south was provided to control summer sun, but include winter solar gain.

The four-lamp lighting system was converted to three-lamp fixtures, with switching for one- or two-lamp operation. Lighting energy dropped from 33,000 Btu/sq ft/yr to 16,500 Btu/sq ft/yr. The redesigned HVAC system increased the use of water-cooled heat pumps and decreased the use of all-air single-duct systems. Total energy use decreased from 95,100 Btu/sq ft/yr to 48,600 Btu/sq ft/yr, a 48 percent reduction.

Example 2: Elementary school in San Diego, Ca. Architects, Deems/Lewis & Partners; engineers, LSWB Engineers. This is a typical 45,000-sq-ft, one-story elementary school located in a very mild climate, where moderate seasonal temperatures and ocean breezes prevail.

The redesign used available daylight and natural ventilation. North-facing clerestories allow soft, uniform light while minimizing solar heat gain and potential glare. Brightness was controlled at the clerestories with antiglare louvers. The artificial lighting system used photocell controls for further reductions. Overall lighting energy use dropped by 77 percent from 12,700 Btu/sq ft/yr to 2900 Btu/sq ft/yr. Natural air movement provided the main cooling source. The original cooling system was totally eliminated. Instead, ventilation louvers in loft areas were used. The redesign effort resulted in a 70 percent reduction from 44,100 Btu/sq ft/yr to 13,100 Btu/sq ft/yr.

Example 3: Daylighting. In this example, we do not present a specific building, but rather typical applications of a design strategy that was used in over 75 percent of the redesigns in a wide variety of forms. Daylighting is a strategy with significant energy conservation potential. The attached graphic depicts possible solutions for an original office building. The items below the graphic list typical changes that occurred as the design was made progressively more energy efficient.

Acknowledgments

Key contributors to the original research program have included: Many individuals within DOE and HUD; the redesign team firms and individuals; the AIA Research Corporation; the National Institute of Building Sciences; Pacific Northwest Laboratories; members of the Technical Advisory Group from a number of professional associations; Syska & Hennessy; The Ehrenkrantz Group; Heery & Heery; Hanscomb Associates, Inc.; Brown Associates.

168 proof?

Over the last year, this series of energy-conscious design articles has taken a fresh look at the largest building research project ever undertaken: the energy redesign of 168 building designs in 13 building types as part of DOE's Building Energy Performance Standards (BEPS). Although many design professionals are aware of the controversial regulatory aspects of BEPS, an analysis of the actual redesign strategies forming the technical basis of the design energy budgets has never appeared in print prior to this series in P/A.

This effort has been funded by Battelle/Pacific Northwest Laboratories under a program sponsored by the Buildings Division of the U.S. Department of Energy.

This article series forms the basis for a comprehensive Battelle report on the redesign experiment entitled "Energy Conscious Design: Redesign Strategy Summaries from the BEPS Phase II Research," which will soon be available for sale by the National Technical Information Service (NTIS), 5225 Port Royal Road, Springfield, Va. 22151.

After reflecting on the six technical articles in this series discussing the redesign of 12 different building types, we have come to a number of conclusions regarding the targets of opportunity in energy-conscious design. We have found the consistent application of several design strategies and have identified noticeable patterns in the application of design strategies that cut across many of the building types where similar energy concerns are shared. These strategy patterns in the redesigns led to a regrouping of the building types originally used in the experiment into three basic categories: offices, including clinics and schools because of similar energy relationships; retail buildings, which we have further subdivided; and buildings that contain a mix of residential spaces as well as service areas.

Because of similarities in usage patterns and functional space mix, highly individualistic buildings can be grouped into generic types. From an energy standpoint, a working knowledge of the energy impacts of usage patterns and space use is invaluable to designers, especially in the preliminary design phase when initial decisions can have enormous impact on subsequent energy efficiency. A regular daytime occupancy profile, for example, raises a different set of concerns from those found in buildings used predominantly at night, because internal and solar loads affect heating and cooling requirements in dramatically different ways. Also, space use in the building determines the predominant environmental conditions to be maintained, as well as artificial lighting levels and certain envelope criteria, such as window area.

Awareness of the relative impact of these factors is essential to the selection of appropriate design strategies for a given building. The use of design analysis tools to predict results can fine-tune the design and provide a higher level of confidence in their selection.

Offices

Small and large offices, clinics, and elementary and secondary schools all share a predominant daytime occupancy pattern. The diurnal heating and cooling problem, which was evident in

the office building analysis, is also found to apply to both clinics and schools. In these buildings, internal loads due to lighting, occupants, and equipment impose a cooling requirement even in cold climates. During periods of little or no occupancy, the situation is reversed, and heating loads due to nighttime conduction losses are of concern. Depending on the climate, most of the annual heating consumption can occur during unoccupied periods in these buildings.

In response, strategies that reduce conduction losses were frequently used. Surface-to-volume ratios shrank, insulation levels were improved, and nonconditioned spaces were often placed as buffer zones between a conditioned space and the building's exterior. Building reorientation, primarily in the small offices, clinics, and schools, allowed the redesigners to take advantage of controlled solar exposure on a seasonal basis.

Control of solar gain was found to be especially important in these buildings. A main redesign trend was the non-uniform treatment of the building envelope depending on solar exposure. Window area reduction, selective reorientation of glazing, and use of both internal and external shading devices were the major solar control strategies employed. These strategies respond to the dynamic interaction of internal loads and solar gains that change by exposure over the course of a day.

Artificial lighting is a major end use in offices, clinics, and schools, and much emphasis was placed on the reduction of artificial lighting and use of efficient luminaires. Lighting reduction lowers internal heat gains from lighting fixtures. Daylighting strategies were emphasized in offices and schools, much more so than in other building types. Thus many of the redesigned building forms were markedly different from their original configurations.

HVAC equipment selection and control strategies were quite similar for the large and small offices and the clinics. Redesigners of these building types consistently chose variable air volume

(VAV) systems over constant volume systems in the larger buildings, and selected heat pump systems in the smaller ones. School HVAC systems tended to rely more on control modifications than on equipment replacement. Control flexibility is key to handling the intermittent usage patterns and variable loads resulting from the multiple use characteristics in many educational spaces. With the combination of all redesign strategies, the offices, schools, and clinics achieved some of the highest energy reductions in the experiment: 40-50 percent.

Retail stores

Retail buildings were originally classified as stores and shopping centers. To examine the retail redesign strategies in more detail in these articles, however, these buildings were reclassified as regional, neighborhood and strip shopping centers, and department stores.

The merchandising orientation of retail buildings naturally places design emphasis more on the building's interior systems than its façade. In contrast to buildings in the office category, retail facilities are less concerned with the dynamic solar load conditions, since they typically have minimal window areas. Instead, high and uniform internal loads due to lighting and occupants impose almost "steady state" cooling loads on the building at given weather conditions. Therefore, the redesign teams retained the original constant volume HVAC systems, but also applied many control strategies to minimize space conditioning energy. Economizers, exhaust air heat recovery, and time-of-day HVAC controls were particularly effective.

Artificial lighting energy, which is often about 35 percent of the total annual energy usage, was a natural focus of attention in the store redesigns. Major lighting trends included the reduction of installed lighting capacity and switching from incandescent to fluorescent fixtures. Daylighting applications were mostly restricted to public circulation areas in regional shopping centers where walkways can comprise as much as one-third of the artificially lighted area.

Site, form, and orientation strategies may have had little apparent impact on energy reductions, except perhaps in strip shopping centers. Retail facilities are often subject to rigid site constraints. Roof area is often significant in this building type, and reflective roof treatments and added roof insulation have the potential to be effective.

Residential occupancies

The occurrence of significant redesign trends common to buildings that share residential occupancies has led us to group together high- and low-rise mul-

tifamily buildings, nursing homes, hotels and motels, and hospitals.

While these buildings are quite dissimilar in many ways, they all share the common attribute of sleeping rooms attached to some type of service area. The continuum of functional space mixes can become increasingly complex from an energy standpoint as service areas comprise larger portions of the building program.

Guest rooms, patient rooms, and dwelling units have similar usage profiles and, to some extent, similar physical characteristics. They are generally occupied at night when outside temperatures can be at their lowest. Temperature setpoints are generally high, which sets the stage for high conduction losses over an extended period of time. Vision glass in these spaces often contributes to nighttime conduction losses as well as solar gains. When uncontrolled, these gains impose substantial daytime cooling loads on the space and its systems. This same glazing, however, can also be properly oriented and shaded for beneficial solar gains to offset heating losses if mass storage is provided.

Design approaches directed toward these energy concerns were applied to sleeping rooms in all these disparate building types. Wall and roof insulation was increased, glazing areas were reduced, building forms were made more compact, often with selective reorientation of south-facing glass. However, the requirements for environmental conditions in hospital patient rooms and for those in nursing homes may limit the use of passive solar strategies more so than in multifamily dwelling units and in motel and hotel guest rooms.

The difference in energy complexity among buildings that include sleeping areas is most evident in the mix of service areas to which these spaces are attached. In multifamily buildings, for example, these service areas or common spaces may be predominantly circulation areas with few internal loads. In other cases, service areas can range from large commercial kitchens in hotels to ancillary and support service areas in hospitals in which strict environmental conditions must be maintained. Although the exact nature of the space and its usage may determine (and even restrict) the design strategies applicable to it, service areas all share the potential for centralized control of energy use.

In the common spaces of multifamily buildings, centralized control was incorporated into HVAC systems for both recreation areas and corridors. Lighting

Over the past five years, over \$30 million has been spent on research initiated to produce "baseline" data on the energy performance of new buildings and to determine maximum practical levels of potential annual energy conservation for the designs of new buildings. The effort was primarily to develop a data base that did not exist at the time to support the proposed Building Energy Performance Standards (BEPS). In these articles, the authors have attempted to strip away the regulatory issues that have obscured what the redesign teams accomplished, and to present it in a useful format. These articles have included:

A baseline for energy design (April 1982), which provides an introduction to the series, briefly describes the principal individual elements of the research, and presents overall results and observations.

Energy design of office buildings (June 1982), which focuses on the major redesign strategies used in small and large offices to address the characteristic concerns of diurnal heating and cooling and dynamic solar gains.

Energy for sales (August 1982), which emphasizes effective redesign strategies for retail buildings and discusses interior systems, such as lighting and HVAC, in characteristic internally loaded steady-state operation.

Dwelling with energy (October 1982), which concentrates on energy strategies for high- and low-rise multifamily dwellings and revealed that solar control and architectural design features play a surprisingly influential role in energy use.

Bed, board, and Btu's (December 1982), which examines the diversity of nursing homes, motels and hotels as a continuum, with increasingly complex relationships between sleeping rooms and service areas. Relocation of spaces, outside air reductions, and shell tightening are a few of the strategies employed.

Energy to recover (February 1983), which highlighted HVAC and heat recovery strategies that were key in dramatically reducing hospital energy use without compromising health care criteria.

Energy: a class by itself (March 1983), which concludes that the energy importance of intermittent usage patterns inherent in elementary and secondary schools resulted in design decisions that enhanced the use of natural lighting while minimizing conductive gains and losses. Mechanical system controls for idle spaces were also important contributors to higher than average energy savings.

STRATEGY MATRIX: PHASE II REDESIGN TRENDS

systems for these spaces were put under the control of timeclocks. More elaborate strategies were used in hospitals to control strict environmental conditions by a strategic rezoning of hospital functional spaces to group together areas with similar environmental requirements on the same HVAC system.

Service areas are also often characterized by the presence of high internal loads caused by lights, equipment, and processes. Spaces such as these are candidates for the application of various heat recovery systems, such as exhaust air heat recovery. Also, a substantial portion of the cooling load in these spaces can be handled with economizer equipment. From a space usage standpoint, service areas, mechanical storage rooms, and corridors are often useful as buffer zones that can shield other conditioned spaces from conductive heat loss or solar gain when properly located.

Research shortcomings

The redesign experiment was complex and fast-tracked, and subject to a number of geographic, energy, and economic analysis shortcomings. Building samples were limited to 37 different cities throughout the nation. In many instances, buildings from the Rocky Mountain states and the Sun Belt were underrepresented or not represented at all.

There also were flaws in the data. The energy analysis computer program, while sophisticated for its time, was unable to estimate the energy savings due to daylighting strategies or those attributable to the use of the temperature "deadband." There were also certain data handling errors, which resulted in unrealistic end use estimates for service water heating and appliance usage in certain building types. More important, energy usage and internal loads from "process" equipment were not included in the energy analysis because of certain policy decisions.

ENERGY END USE PERCENTAGES (PERCENT OF TOTAL ANNUAL ENERGY)

A significant shortcoming to the redesign experiment was the lack of economic analysis to test the cost effectiveness of the redesign strategies. Economic data for the redesigns are limited to the change in first cost of construction in the redesign compared with that of the original building, a crude measure at best. The only detailed economic analysis performed was that of a life-cycle cost study conducted on three office buildings one year after the major research was completed.

We feel that these limitations do not invalidate the basic findings of our research and the conclusions on energy characteristics and strategy patterns. We do think, however, that a different set of design strategies could have emerged if the major objective of the original BEPS research had been to reduce energy costs instead of energy consumption.

Had the pricing structure of energy types been explicitly taken into account, it is certain that more emphasis would have been placed on the reduction of electric demand, for example, and perhaps less emphasis on reducing fossil fuel consumption for space and service water heating. Current building research, with its emphasis on cost effectiveness, has taken this cue.

Another major obstacle in the series was that the data from which we worked were not intended to evaluate the energy effectiveness of particular design strategies. While the particular strategies used were known, and their combined impact determined, the individual impact of each design element was often unavailable. "Whole building" energy results came from a combined package of redesign strategies. Analysis of incremental effects often involved using the redesigners' estimates, or even our own. The broad patterns for design options were evident, however, even if individual contributions could not be segregated.

The results

The principal product of the original BEPS research, from a design standpoint, was the development of design energy targets in a consistent and methodical manner. Ranges of energy use for 13 commercial building types in 78 geographic locations are now available for use by design professionals. Other DOE studies on contemporary energy-efficient building designs have shown that these targets are both reasonable and achievable.

The research for this series has looked beyond these abstract energy numbers to identify an additional set of products: the actual architectural and mechanical design strategies responsible for the substantial energy savings achieved by the redesign teams. The patterns of using these strategies in the redesigns are useful generic design data that can be effectively used by designers, especially in the early stages of design. □

Opposite: The strategy matrix, end-use percentages, and overall averages for selected energy parameters highlight the trends found in the Phase II Redesign experiment. Only the energy end-use percentages and energy parameters are based on quantitative data. The strategy matrix reflects the authors' judgment and observation of recurrent trends.

The high incidence of HVAC strategies in the retail category stems from the fact that these buildings can be best characterized as opaque shells that are internal-load dominated. Accordingly, the redesigns concentrated on targets of opportunity such as economizer and deadband controls, exhaust air heat recovery, return air troffers, process cooling heat recovery, and low static pressure distribution systems.

The offices category, by contrast, is characterized by high vision glass requirements (giving rise to coincident heat/cool demands) and a pattern of use in which these buildings are internal-load dominated during the day and skin-load dominated at night. Consequently, in this category we find the whole range of conduction reduction strategies (form compaction, unconditioned buffer zones, U-value upgrading, etc.) in addition to a very active management of the shell with regard to interior and exterior shading, glass orientation, and daylighting. System strategies included high efficiency lamps and fixtures, illumination reductions, multilevel and zone switching, HVAC distribution system changes, deadband and economizer controls, temperature setbacks, and heat recovery from condensers and exhaust air.

Patterns in the residential group vary somewhat with the complexity and nature of the support services. This category is very often skin-load dominated with high vision glass requirements. Again, we found the recurrent use of conduction and solar control strategies in addition to the application of some passive strategies (mainly in nursing homes and multifamily low rise). Heat recovery in all forms was also popular, mainly because of the multiplicity of process heat sources and demands.

The energy end use percentages in the original designs show the targets of opportunity available to the redesign teams. After the redesign and subsequent energy reductions, new end percentages present a new set of priorities for achieving further reductions.

The changes in overall averages in energy parameters, from the original building values to the redesign, support the identification of strategy trends. The variation in the parametric changes reflects not only the difference in conservation potential among the building types, but the original level of energy awareness in the redesign teams.

Feedback

In January, the authors of this series presented a summary of their research results at a seminar held in conjunction with the 30th Annual P/A Awards. Following the presentation, a panel of P/A Award winners and energy experts, moderated by series editor Richard Rush, discussed the articles and related design topics. Comments were then solicited from award winners and guests in the audience. Highlights of the discussion are presented in the second part of this article. Readers of P/A are encouraged to continue this feedback process with letters and expressions of their own opinions of the value of this article or any in the series.

Rush: From your experience as the designer of specific buildings, what is the relevance of a broad generic study such as this to your practice?

Mack Scogin: I think that what happens to a lot of people like myself who are somewhat neophytes at dealing with technical issues like energy is that we began to look at these kinds of articles and say, "Oh, my God, here's something else I need to know something about, and I'd better start doing something about it." What we've discovered over the last couple of years in our projects is that a lot of these norms and the intuitive responses developed after reading or scanning these types of articles are not necessarily applicable to specific buildings. Therefore, I think care must be taken with these sorts of generic articles not to overlook the fact that people have very, very simplistic responses to them. Don't be embarrassed as an energy expert to admit that this is a very complex problem and present it that way.

Rush: Donn Logan, does your experience in designing the San Jose State Office Building correspond to the overall trends represented in the series and if not, how does it differ?

Donn Logan: The State Office Building in San Jose would fall into the large office building category. It has more than 50,000 square feet (it's about 130,000 square feet), and yes, it does support the trends in a general way. I think we did, at least our computer printout says that we will, a little bit better with the general numbers. We may be down to 26,000 to 28,000 Btu's per square foot. The strategy we used emphasized daylighting more than some of the sample buildings.

Rush: What are the relative merits of an architectural magazine publishing a series of individual buildings as opposed to a series of articles about various building types? Should there be more emphasis in the press on such research?

Joseph Fleischer: There are a lot of very good bits of general information contained within the articles that one can get lost in, and they're the kind of things that we all do know exist and rarely, if ever, I'm afraid, apply to the general building design. It has a lot to do with the priorities that certain offices establish and the way in which they approach their designs. The use of the generic building types is important in that it gives us all general directions. Far too many people in the offices and in the profession, particularly the decision makers, are not oriented to this type of article per se, but more oriented towards understanding specific buildings and the way in which the problems were solved within those buildings.

Rush: Harrison Fraker, what studies of a similar nature could the government fund that would have a similar value to the profession?

Harrison Fraker: I'm primarily a designer and a teacher, so I'm interested in the nature of the information in these articles that reveals to a designer why a building loses energy in the patterns that it does. I think the work that P/A has done in this area in bringing out the beginning understanding of such reasons is commendable. But I think we're a lot wiser now, and I think we can take the work quite a bit further.

Before 1978, we didn't even know how much energy each of these building types used, and this first step at least breaks the energy use down by end use so we know how much is used for heating, how much for lighting, how much for cooling and hot water. That information is a first step, and we can begin to understand what causes the changes in the redesigned building. I'm interested in taking that information and taking each of those end-use areas and showing why a building uses so much for cooling, why it uses so much for heating, and so on. When designers identify the major targets of opportunity, they can then address those aspects of the building or the whole system that will really make significant reductions in the use of energy.

Another step of the process is what happens when utility costs are added to these numbers. In many places the biasing structure of the utility sets the priority on design strategies much more than

the building form and envelope and shape, and much more than the mechanical system. Here's an example. In the energy consumption in hotels and motels, the overall Btu consumption for hot water is relatively low. The manager of a hotel will tell you the number one priority is domestic hot water. The designer has to ask why. The reason is that all the hot water is used in one hour and in most cases there is a huge demand upon the system. If all you analyze is the energy, you wouldn't think it was a problem. If you analyzed the dollar consumption and broke it down into both dollars consumed for energy and demand, you would see that it is a number one priority.

Rush: We'll ask Ted Kurkowski of DOE to address this next question. Would a government grant to construct 60 buildings each costing a half million dollars yield more valuable information than a \$30 million research project such as BEPS?

Ted Kurkowski: My reaction to the question is that a program that intends ultimately to transfer useful information to other people must spend an incredible amount of money documenting what has been done. What would have happened if we had built real buildings rather than the study is that we would have studied only a few buildings, in great detail, and probably not learned as much; we possibly would have had greater acceptance of the data. No money is saved by not building buildings.

Rush: Fred Dubin is in the audience and participated heavily in the redesign program. Fred, do you have some comments?

Fred Dubin: First of all, you can't design a building from any article that's ever written. If you do, it's not the right building. I believe in using specific buildings in the Socratic method of pointing out principles and sensitivities.

The redesign program had tremendously beneficial effects, whether it was worth \$30 million or not. It did provide directions. It also established averages, which is very, very dangerous. If we

The panelists in the photograph from left to right are: Mack Scogin, Heery & Heery; Joseph L. Fleischer, James Stewart Polshek & Partners; Harrison Fraker, Harrison Fraker Architects; Richard Rush, American Institute of Architects; Donn Logan, ELS Design Group; Dr. Vladimir Bazjanac, University of California at Berkeley; Harry P. Misuriello, W.S. Fleming & Associates. Not pictured: Joseph J. Deringer, Gilford, Deringer & Company.

have one foot in the refrigerator and one foot on the stove, the "average" temperature is comfortable. There is a need to do a very specific study for each building and each building type on a specific micro location and micro climate. Perhaps, with the building guidelines that came out of this program, one has an idea of what can be accomplished and then specific goals can be established. There is a great deal more work needed to develop design tools, a design vocabulary, and a library of parts and components information so that architects or engineering designers will know the consequences of their decisions before they have a building.

Rush: John Cable was instrumental in the initiation of this article series while he was still with DOE. John, what are your thoughts?

John Cable: As much information as this series of articles seems to contain, it only scratches the surface. There are some other pieces of good information available if you choose to dig for them. One of the fellows who used to work with me has now been in private practice for a year. I asked for his impressions, having crossed over from research to design. He replied: "I forgot that architects were so overwhelmed with getting a contract, signing a job, administering the contract, working with the client, meeting structural requirements, working with the code officials, getting the building financed, and trying to solve the liability problems." Energy was only a minute piece if at all. I don't know what your future plans are, but I think a book that just has all these articles in it with the summary of what we've learned would be a great desktop piece right beside the usual graphic standards and the structural steel handbook.

Rush: Bob Shibley was involved in a similar study, an analysis of the Owens-Corning award winners. I would be curious to know if he agreed or disagreed with the general conclusions.

Robert Shibley: There weren't any startling surprises. What we did find in the OCF trend analysis was that in the early 1970s we were doing a few energy-conserving strategies very well, and they were being celebrated in award-winning buildings as innovative or ingenious strategies. As more and more strategies became available, the

challenge to the award jury was to relate the strategies and the confluence of all the issues necessary to bring a good quality building out of the ground. As part of that, and I'm going back to Ted Kurkowski's observations, if you have a choice between studying it or building it, and building it and studying it, build it and study it. Only then can we truly understand the implications and the context of anything we have to deal with to build.

Rush: This is the second such DOE-sponsored research effort P/A has been involved in. The first was a two-year study based upon individual computer analysis of chosen buildings, led by Vladimir Bazjanac. Vladimir, what is the difference between the qualitative information one gets from the sophisticated energy analysis of existing single building design and the kind of information obtained from examining 168 buildings or 25 buildings of a specific building type altogether. What can the individual architect do with the two kinds of information?

Vladimir Bazjanac: The 168 buildings do not basically provide you with enough information to be directly useful in the design process. All they can tell you is what might be done, and they give you an idea in the negotiating stages of what energy consumption the building is going to have. Some very useful ranges were produced. I wouldn't try for the exact numbers, simply because of the inconsistencies of methodology over a period of time. What we did with individual buildings was to provide a measure of what is accomplished by varying the design parameters. It was narrowed straight down to a specific set of design decisions that were investigated.

From the BEPS article, one can tell the client what the range of savings might be and what is reasonable to expect. Nothing would be learned about the specific building. Now, if the building was in a climate somewhat like Chicago, say, our energy analysis of Helmut Jahn's building, might produce relevant material.

There were a couple of examples in the BEPS articles that sort of dealt with buildings as we did. They often could not tell you in detail how much those components contributed. But they illustrated how some of those savings might be achieved.

In last April's issue, you used a number of descriptive titles: This is who and where and what. If you use that kind of terminology, ours would be called this is how. The BEPS study could be called this is how much.

Also in attendance:

Bernard Babka, Hammond Beeby & Babka; Robert Beckley, Beckley/Myers; Richard Bozic, Architecture-Research-Construction, Inc.; Harvey Bryan, Assistant Professor, MIT, School of Architecture and Planning; Alan Chimacoff; William Conklin, Conklin & Rossant Architects; Fred Dubin, Dubin-Bloome Associates; Elizabeth Erickson, Shepley Bulfinch Richardson & Abbott; John Eberhard, Advisory Board on the Built Environment; W. Paul Farmer, Planning and Design Partnership; Sheldon Fox, Kohn Pedersen Fox & Associates; Geoffrey Freeman, Geoffrey Freeman Associates; Robert Geddes, Geddes, Brecher, Qualls & Cunningham; Susan Gill, ABRI Design Associates; Raymond Gindroz, UDA Architects; Alan Green, Educational Facilities Laboratories; Robert Gutman; Michael Keihn; Doug Kelbaugh, Kelbaugh & Lee; Jonathan King, Architectural Research Laboratory, The University of Michigan, Ann Arbor; William Lam; Theodore Liebman, Liebman Williams Ellis; Sang Lee, Kelbaugh & Lee; David Lewis, UDA Architects; S.I. Morris; Daniel Pang, Daniel Pang & Associates; Donald Prowler, Department of Architecture, University of Pennsylvania; Peter Ringenbach, Perry Dean Stahl Rogers; Walter Rosenfeld, The Architects Collaborative; James Rossant, Conklin & Rossant, Architects; Peter Samton, Gruzen & Partners; Frederic Schwartz, Venturi, Rauch & Scott Brown; Robert Shibley, SUNY, Department of Architecture; Richard Stein; Thomas Vonier, Thomas Vonier Associates, Inc.; Peter Waldman; Ralph Warburton; Lawrence P. Witzling, Planning and Design Partnership.

Contributors: A number of individuals and organizations have contributed to the development of this article series. Principal researchers: Harry P. Misuriello, Principal, W.S. Fleming & Associates, Inc.; Joseph J. Deringer, President, and Santiago Moreno, Associate, Gilford, Deringer & Company.

Researchers: James Binkley, Chief, and Ted Kurkowski, Program Manager, Commercial Building Systems Analysis, Architectural and Engineering Systems Branch, DOE; John Stoops, Project Manager, Ray Reilly, Program Manager, and Stan Pansky, Project Architect, Battelle/Pacific Northwest Laboratories; John H. Cable, Principal, The Ehrenkrantz Group; Richard Menge, Saudi Arabian Parsons, Ltd.; Roger Easley, Consultant to Battelle; Mike Gilford, Richard Meilan, and Terry Ann Nyberg with Gilford, Deringer & Company; Verna D. Hawkins, W.S. Fleming & Associates, Inc.

ANALYSIS BY BUILDING TYPE

UNIVERSITY OF MICHIGAN LIBRARY

SUMMARY OF SECTION CONTENTS

1. Small and Large Office
 - a. Article: "Energy Design of Office Buildings"
 - b. Building Type Analysis
 - 1.1 Energy Characteristics of Office Buildings
 - 1.1.1 General Overview of Issues and Potentials
 - 1.1.2 Usage Profile
 - 1.2 Building Sample Issues
 - 1.3 Analysis of Redesign Strategies
 - c. Key Energy Parameters - Graphic Presentations
 - d. Key Energy Parameters - Extractions from Computer Stored Data

Energy design of office buildings

This article in the energy-conscious design series will feature the office building research portion of the redesign experiment described in the April issue of P/A (pp. 110-115). It focuses on the key energy design strategies, used by the redesign teams, which contributed to the substantial annual energy reductions accomplished through the office building redesigns.

Contributors: A number of individuals and organizations have contributed to the development of this article. Principal researchers: Harry Misuriello, Principal, W.S. Fleming Associates; Joseph J. Deringer, President, Gilford, Deringer and Company.

Researchers: James Binkley, Chief, Architectural and Engineering Systems branch, DOE; John Stoops, Project Manager, and Ray Reilly, Program Manager, Battelle Pacific Northwest Laboratories; John H. Cable, Principal, The Ehrenkrantz Group; Richard Menge, Director of Architecture, Greenhorne & O'Mara; Roger Easley, Consultant to Battelle; Santiago Moreno, Mike Gilford, and Richard Meilan, with Gilford, Deringer and Company.

As the classic example of commercial buildings, offices were chosen as an appropriate beginning of this series. For the redesign experiment, 22 office buildings ranging from a 3800-sq-ft one-story branch bank to a 637,000-sq-ft 29-story office tower were statistically selected. Half of the buildings were less than 50,000 sq ft, a nominal dividing line between small and large offices for the research. They were located in a wide variety of climates (Figure 2).

Of the 16 building types chosen for overall study, the office building redesigns benefited from some of the largest energy reductions from their original designs. Designers of small office buildings accomplished a 50 percent average annual energy reduction, from 77,200 Btu/sq ft/yr to 39,000 Btu/sq ft/yr. Large office buildings achieved a 42 percent reduction, from 69,000 Btu/sq ft/yr to 40,300 Btu/sq ft/yr. These substantial cuts were accomplished with an estimated 3½ percent average increase in first cost of construction.

Energy design considerations

Office energy requirements for thermal comfort, ventilation, and lighting vary within relatively narrow ranges, except for special functions such as computer centers. Unlike hospitals or restaurants, offices tend to be occupied during regular daytime hours. At night and on weekends, they are often vacant or only sparsely occupied. During office hours, high internal thermal loads can occur from lights, equipment, people, and external solar gain. With a reasonably "tight" envelope, such heat gains can lower the "balance point" (the outside temperature below which a building needs to be mechanically heated) to 40 F or below.

Conversely, the building may need to be cooled while outside temperatures are as low as 40 to 50 F. Control of heat gains can therefore be a predominant energy conservation consideration for occupied periods. At night, during the

heating season, peripheral heat gain sources are normally absent and the temperature is lower. Thus, control of conduction and infiltration losses can be a predominant consideration. In warm climates, control of gains can be the dominant energy factor.

Superimposed on operational regularity is a fluctuating office building layout, changing with the needs of its occupants. A typical design response to the problem of interchangeable space requirements is the use of grid lighting systems that are often controlled in banks by circuit breakers. Such systems can cause large areas to be lighted needlessly for cleaning crews or a few off-hour workers.

There is a variety of interrelationships between energy design considerations. Lighting, for example, is both a major energy end use in office buildings and a major contributor to internal loads. Therefore, energy-conscious design strategies will contain both diurnal and seasonal aspects and take into account many interrelated internal and external factors and their relationships to the building program.

Multituse office buildings present a more complex design and analytical challenge. Their numerous secondary uses can significantly affect design solutions and annual energy consumption. Nearly 40 percent of the designs studied have varying amounts of non-office-related space, although this occurred more frequently in the larger buildings.

Standardized building operating conditions (Figure 1a) used in the computer analysis represent the average operation profile for office spaces reported by the redesign teams. Additional profiles were also used depending upon the functional space mix in a specific building. Despite the similarities in space type and operation, the average annual end use characteristics of the large and small office redesigns appear to be independent of size. Lighting and space conditioning are found in roughly the same proportions in either case and account for over 90 percent of total energy use in both the original and redesigned small and large office buildings (as well as in the ASHRAE Standard 90-75R evaluations). The real difference between

Office buildings

FIGURE 1A: OFFICE SPACE OPERATING PROFILES

FIGURE 1B: INSTALLED LIGHTING CAPACITY

FIGURE 1C: LIGHTING CONTROL TYPES

FIGURE 1D: COMPOSITE U-FACTOR

FIGURE 1E: HVAC SYSTEM TYPES

large and small offices may lie not so much in end use as in the choice and application of particular energy conservation strategies.

Optimizing thermal gains and losses

Orientation, form, envelope, and lighting are the basic design strategies used to control thermal loads. The diversity of solutions possible by combining options is illustrated by the seven redesigns shown in Figure 3.

Orientation: Over half of all the redesigns used reorientation for solar control by siting the building's longer elevation along its east-west axis. A small office in Wisconsin (Building No. 1), for example, oriented its light scoops and attached sunspace due south for maximum solar contribution. Similarly, the recessed fenestration and newly elongated form on a large office in Connecticut (5) was turned toward the sun.

Form: In only a few instances was the building form left unchanged from its original design. Reducing the surface-to-volume ratio was tried in a small office in Bakersfield, Ca (11), in a climate where cooling loads dominate. Less roof area is exposed to the sun, controlling conductive solar gain. Stairwells and mechanical spaces were moved to the southern exposure as unconditioned buffer zones for control of solar gain, and glazing was eliminated from east and west façades. One means of controlling heat loss from glazing, while admitting natural lighting, is to use a central interior atrium as in the Pennsylvania large office (15). Its slightly elongated form was also compacted around the atrium, providing a more advantageous surface-to-volume ratio.

Envelope: An important redesign trend was the nonuniform treatment of glazing and shading for each exposure. In all but the most severe cooling-load climates, glass distribution generally "migrated" towards the building's southerly exposure and was minimized or eliminated on the north, east, and west. Such migration was not so pronounced for large offices. But a combination of glass types and interior shading devices was selected to provide appropriate window shading coefficients for each exposure regardless of building size.

In a small building (4) in Minnesota, glazing was eliminated completely on the north and concentrated on the south exposure. With the glazing shaded in summer (but not in winter) by a series of set-in overhangs and using slanted glass, solar gains to the conditioned space are controlled seasonally. By contrast, in a

SMALL OFFICES—NO'S 1-11 LARGE OFFICES—NO'S 12-22
FIGURE 2: 22 BUILDINGS IN 17 CITIES IN CONTINENTAL U.S.

climate where the predominant load is cooling, a small office (10) in Louisiana redistributed most of its glazing to a north-facing clerestory, which accommodates both daylighting and solar control. These examples are interesting because they all seem to be reasonable, given the other design strategies that were employed. In other words, orientation, form, and exposure treatment are all interrelated; one cannot be viewed completely apart from the others.

A third of the small office redesigns, predominantly buildings of less than 20,000 sq ft, used either direct gain or passive thermal storage strategies. Unlike large multizone offices, these smaller buildings have less distinction between interior and perimeter zones, and it is easier to locate the storage mass in physical proximity to both the solar aperture and the conditioned space. Both large and small office redesigns, however, used orientations, form, and fenestration to control and use solar gains on a seasonal basis even without thermal storage.

Conduction: Strategies aimed at reducing conduction losses can be important in climates where night heating is of concern. In nearly 75 percent of the office redesigns, the trend was to improve the composite "U" factor of the envelope as shown in Figure 1d, by manipulating the component "U" values of walls, roof, and glazing. Also, glass area as a percent of wall area tended to diminish as did roof area as a percent of total exposed area. In predominantly heating climates, wall and glass "U" factors of the small offices were improved only slightly. In cooling climates the redesign trend was to add double glazing. Glass area was reduced in all climates, except in those instances when it was increased in conjunction with passive thermal storage, direct gain strategies, or daylighting. Although the average composite "U" factor for large offices was reduced, the changes in individual component values did not reveal any particular trends. Such differences illustrate that overall thermal integrity in

Life cycle cost analysis (LCC)

Detailed life cycle cost (LCC) analyses were conducted on three all-electric office buildings (4, 17, and 18) to learn more about cost effectiveness at various energy levels. Energy analyses and detailed cost estimates were made for additional conservation strategies. For the three buildings, design energy consumption estimates in the mid or low 20,000 Btu/sq ft/yr range were obtained. While not completely analyzed from a building owner's or developer's perspective, the majority of design strategies were cost effective when compared with the original buildings, based upon Federal Government LCC economic parameters and a projected 40-year building life.

Figure 4 shows selected results of design changes from those tried on the large office in Raleigh, NC (18). Even with an efficient lighting system, about half of the annual energy for the redesigned building was for lighting. Daylighting and task lighting became obvious targets of opportunity for further reductions. Several alternatives were tried. In one, the A/E team reconfigured the building to make daylighting available for over 40 percent of the office space. An alternative with no glazing on east and west walls still provided more access to daylight than the redesign. These solutions used daylighting and task lighting and resulted in 15 to 20 percent energy reductions from the redesign, as did a task-lighting strategy based on the redesign.

ASHRAE Standard 90-75R analysis

Among the results of the redesign experiment was an analysis of ASHRAE Standard 90-75R, which forms the basis for building energy code requirements in over 47 states. The original office building designs were configured to meet an exact interpretation of the requirements of Standard 90-75R and analyzed with the same computer program and operating profiles used for the original buildings. In all but one instance, the application of Standard 90-75R caused annual energy consumption to decrease by an average of over 27 percent in all offices (Figure 5). In most cases, the office redesigns reduced energy levels to below those resulting from Standard 90-75R. For small and large office redesigns, additional savings of 32 percent and 17 percent, respectively, were achieved. The energy performance of the rest of the redesigns demonstrated that there was room for improving the stringency of these minimum code requirements.

FIGURE 4. ENERGY AND COST RESULTS FOR NINE ALTERNATIVES TO PROJECT 18, RALEIGH, N.C.

small offices, with their higher surface-to-volume ratios, is generally more important than in larger ones.

Lighting: Nearly all the redesigns reduced the installed lighting capacity in watts per sq ft (Figure 1b). On the average, installed capacity was reduced from about 2.7 watts/sq ft to around 1.7 watts/sq ft. The redesign teams used one or more of the following: reduced illumination levels; more efficient fixtures, lamps, and controls; task lighting; reduced use of incandescent fixtures; and daylighting. These strategies lower annual lighting energy consumption, help control heat gain in conditioned spaces, and reduce cooling loads on HVAC systems.

Daylighting strategies of many variations were tried in two-thirds of the office redesigns. Unfortunately, the computer model used in the redesign analysis could not evaluate daylighting at that time, so the potential energy reduction is not known. While a limitation, it does highlight that the average 38 to 40 percent annual lighting energy reduction was achieved by "conventional means." Daylighting can reduce artificial lighting energy use even further and therefore has significant potential (Figure 4).

As shown in Figure 1c, large office lighting system controls are far more complex than those in small offices. Some of these control types were to implement daylighting strategies (e.g., photocell controls), but can also be used to control lighting use during fully or partially unoccupied hours by using switches instead of circuit breakers.

The redesign results suggest that effective lighting strategies are not dependent on building size. Building size, site, and function mix, however, can have a bearing on which lighting strategies are appropriate.

HVAC systems: There was a strong trend toward the use of more energy efficient HVAC systems (Figure 1e). Larger offices used more variable air volume (VAV) systems while heat pumps became dominant in small of-

fices. Use of less energy efficient constant-volume systems (either single or dual duct) was reduced by approximately half. Five of the eleven small offices switched to predominant or total use of hydronic heat pumps. Also, the two larger offices, which switched to heat pumps, were less than 60,000 sq ft in gross area.

Small office HVAC systems tended to use unitary or rooftop equipment, while central systems were more prevalent in the large offices. In large offices, moreover, a significant shift away from separate heating and cooling plants toward combined systems using heat recovery was observed. While only one of the original offices used chiller heat recovery, five of the redesigns incorporated this strategy.

Cooling with outside air using an economizer cycle is a simple and reliable strategy that was already used by nearly half of the original buildings. Four of the remainder adopted them as part of the redesign. Those that did not used natural ventilation strategies instead.

The control of the total building thermal load through architectural and lighting strategies was probably a major influence in reducing the installed cooling capacity from the original to the redesign, primarily in the small offices. The specific reasons for this trend are not clear, as a detailed analysis of equipment sizing was not performed.

Among HVAC control strategies, a space temperature deadband was most frequently specified. In those buildings that originally employed this control strategy, the deadband range was typically extended by a degree or two. The effect of this strategy on annual space conditioning energy consumption could not be determined for the redesigns, as the computer model was not able to simulate it. However, the ASHRAE Standard 90-75R results shown in Figure 5 were analyzed a year later after the deadband capability had been added, and include a 10 F deadband for buildings with appropriate systems. This limitation implies that space conditioning energy reductions for the redesigns are understated.

Observations and conclusions

Some overall lessons of the office redesign process:

- It is important to interrelate energy-conscious design strategies to achieve effective control and reduction of energy usage.
- Energy-conscious design strategies need not be exotic. Careful and thoughtful combinations of "conventional" design strategies were effective for a number of buildings.
- Control of heat gains, especially from lighting and solar, is an important design consideration for occupied and unoccupied periods.
- As a building design becomes more energy efficient, the major targets of opportunity can shift. Typically, lighting energy strategies become more important.

The office building redesign experiment left many unanswered questions. For example, because consistent and detailed cost data reporting was not required, it is not certain whether the redesign strategies were cost effective. This was a major shortcoming in the redesign research effort. From a technical standpoint, complete energy estimates for the performance of passive solar redesigns were not obtained, as the computer program used in the analysis was not oriented towards these strategies. Similarly, daylighting systems could not be modeled, and the energy results do not include these strategies. Many current energy analysis programs, however, do not have these limitations. With the exception of the three offices used in the LCC analysis, no follow-up reporting was done to compare actual energy consumption of the original buildings to the research estimates. For the three LCC buildings researched, however, this comparison was reasonably close.

While the research has certain shortcomings, it has also produced design energy targets for office buildings that are technically achievable. Recent studies and articles have contained reports of both current energy-conscious building designs and recently constructed buildings with annual energy performance in the range of the redesigns. But more must be learned about the cost effectiveness of design strategies. Efforts are now underway to identify cost-effective energy design strategies for small offices, using the redesign experience as an effective point of departure. □

FIGURE 5. ANNUAL ENERGY END USES FOR REDESIGN EFFORT

b. Building Type Analysis: Offices

Office building redesigns benefited from some of the largest energy reductions from their original designs. Designers of small office buildings accomplished a 50% average annual energy reduction, from 77,200 Btu/sq ft/yr to 39,000 Btu/sq ft/yr. Large office buildings achieved a 42% reduction from 69,000 Btu/sq ft/yr to 40,300 Btu/sq ft/yr. These substantial cuts were accomplished with an estimated 3 1/2% average increase in first cost of construction.

1.1 Energy Characteristics of Office Buildings

The following sections define issues, potentials, usage profiles and typical end use percentages for the office buildings sample.

1.1.1 General Overview of Issues and Potentials. Offices are generally best characterized by high vision glass requirements, high lighting loads, and a predominant daytime occupancy pattern. These characteristics give rise to dynamic load variations by exposure during the day (along with coincident heating and cooling demand) with an internally load dominated condition during the day and a skin loaded dominated condition at night.

Consequently, in this building type the Phase II redesign teams applied a wide range of conduction, solar control, lighting and HVAC systems strategies. The following concerns and associated strategies are significant:

- . NIGHT CONDUCTION LOSSES
Strategies:
 - . Form Compaction
 - . U-value Upgrading
 - . Unconditioned Buffer Zones
- . SOLAR GAINS FROM HIGH VISION GLASS REQUIREMENTS
Strategies:
 - . External Shading
 - . Internal Shading (including glass type selection)
 - . Self Shading
 - . Building Reorientation on an E-W Axis
 - . Building Elongation

- . Selective Glass Orientation
- . HIGH LIGHTING LOADS
Strategies:
 - . Illumination Level Reductions
 - . Daylighting
 - . Return Air Troffers With or Without Economizer Cycles
 - . Multilevel Switching
 - . High Efficiency Lamps and Fixtures
 - . Task Lighting
 - . Timers
- . HIGH INTERNAL LOADS
Strategies:
 - . Economizers
 - . Condenser Heat Recovery
 - . Exhaust Air Heat Recovery
- . DYNAMIC LOAD CHANGES/COINCIDENT HEATING AND COOLING
Strategies:
 - . Closed Loop Heat Pump Systems
 - . Variable Air Volume Systems
 - . Chiller Part Load Strategies
 - . Variable Auxiliaries
 - . Variable Speed Chillers
 - . Heat Recovery from Interior Zones
- . COINCIDENT SOLAR AND INTERNAL LOADS
Strategies:
 - . Heat Storage Systems for Night Heating, Reheating or Preheating
 - . Collection of Energy on the South Exposure to Assist Heat Pump System with or without Storage

The relevance of the above strategies varies considerably with climate, and with specific building program or site requirements. Also, energy conserving design strategies must be interrelated to be effectively implemented. Implementation of one strategy may either require or exclude the use of other strategies.

1.1.2 Usage Profile. The usage profiles of office buildings were estimated by the redesign teams. These estimates are characterized by the following:

- o Space Use
 - o Office
 - o Circulation
 - o Interchangeable Space
- o Usage Profile
 - o Day Time Occupancy
 - o Minimal Night and Weekend Usage

Refer to Figure 1A in the Offices Article for the predominant office operational profiles. This document contains estimates of hours of use and other parameters for each major space use type within office buildings.

1.2 Building Sample Issues

Twenty two office buildings ranging from a one story, 3,800 square foot small office to a 29 story, 637,000 square foot large office were selected for the redesign effort (of these twenty two buildings, eleven are small offices). However, 90% of the sample is under 300,000 square feet.

From the standpoint of climate distribution, the building sample was representative of most climate conditions with the exception of hot arid climates.

The original 50,000 square foot distinction between small and large offices used in the research was maintained in this analysis. Some differences between large and small offices impacting energy strategies include:

- o In most cases large offices can be expected to have smaller surface to floor area ratios than small offices.
- o Large offices can be expected to be more site constrained. Consequently, orientation and form generally are not as flexible as in small office buildings.
- o The cost implications of changing the exterior facade to fit a particular strategy are of a higher order of magnitude in large than in small offices.
- o Solar gain on roofs will be more significant in small offices.
- o The issue of central versus local packaged equipment relates primarily to small offices.

1.3 Analysis of Redesign Strategies

The efforts of the Phase II teams in redesigning large and small office buildings proved quite effective in reducing estimated annual energy use. Comparison of computer analyses of the energy consumption of the original and redesigned buildings showed a reduction of 42% in large offices and 50% in small offices from the original building designs. For the most part, this reduction was due to application of standard conservation strategies. Most of the twenty-two buildings in the sample were reoriented to an east-west axis and, in several cases, bermed. Envelopes were tightened, U-values were reduced and glass selectively oriented and used in conjunction with external shading devices.

Fluorescent lighting was adopted or its use increased in all buildings, whereas incandescent lighting was either reduced or eliminated entirely. Illumination levels were reduced and daylighting techniques applied. Constant volume HVAC systems were replaced in large office buildings by VAV systems, and hydronic heat pumps were adopted in many of the eleven small office buildings. The dead band range was extended a few degrees in half of the redesigns.

The results highlight certain trends and support the statement that standard conservation strategies can be widely applied to office building design and will yield significant reductions in building energy consumption.

Siting/Envelope. The most significant trends observed were the reorientation of buildings on an east/west axis and the tightening of the envelope via the upgrading of U-values for walls, roofs and glass. Glass areas were reduced an average of 20% and 11% in small and large offices, respectively. However, glass areas were increased in cases where passive solar or daylighting applications were attempted or in cases where climate conditions were mild (e.g., San Diego). Berming was observed in 30% of the redesigns, while deliberate attempts to compact the form were very few.

Active management of the building shell with regard to solar control strategies was apparent. In the case of small offices, glass areas migrated to the south elevations in cold climates and to the north elevations in predominantly hot climates; external shading devices and self shading schemes were used in most cases for the seasonal control of solar gains. In some instances interior shading coefficients were increased, mostly in buildings relying on passive designs.

In small offices the incidence of passive solar systems was high. For the most part, designs were geared to assist hydronic heat pump systems with thermal storage, i.e., solar radiation collected in the south exposure was not to only be used to satisfy the daytime heating demands of other zones but was also stored to be used to maintain setback temperatures in the building at night. Some other examples of redesign approaches include:

- o Direct gain system tied to a closed loop air to water heat pump with storage tank. The system is also used to preheat domestic hot water.
- o Solar absorbers mounted on the return air duct work.
- o Sun space tied to an air to air heat pump. No storage.
- o Passive solar duct for attic venting.

In large offices solar control trends were somewhat different. Glass migration was similar to small offices. However, for shading purposes, designers had a tendency to place a higher reliance on the manipulation of shading coefficients by varying the glass types or using reflective blinds. There was significantly less use of external shading devices than for small office buildings.

Envelope strategies receiving scattered attention were:

- o Reflective roofs
- o Thermal shutters for night insulation
- o Use of unconditioned buffered zones

Lighting. The significant reductions in installed lighting capacities were primarily caused by across-the-board illumination level reductions and secondarily by replacement of incandescent lamps for fluorescents.

Daylighting could not be modeled by the energy analysis program used at the time. The annual energy results shown here do not reflect the conservation potential of the daylighting strategies tried by the design teams. However, qualitative analysis of the redesigns clearly shows a great concern with the application of daylighting techniques. Photocell control applications were much more prevalent in the large offices, while small offices relied for the most part on on/off manual controls and partially on manual two-step dimming controls. Lighting strategies that received scattered attention were:

- . High efficiency ballasts
- . Parabolic lenses
- . Task lighting with HID up lights
- . Daylight borrowing
- . Interior atria: This particular strategy can be quite effective since not only does the interior atrium increase the perimeter of the building, increasing then the potential for daylighting, but it can also function as an unconditioned buffered zone and limit both conduction losses and solar gains.

HVAC. One of the most significant byproducts of the redesign process was the overall impact of conservation on installed capacities. In large offices, cooling and heating installed capacities decreases 39% and 53%, respectively, while in small offices reductions of 7% and 72% were achieved (See graphic presentations Figure 1.8).

In terms of systems, large office redesign teams decreased use of constant volume reheat systems in favor of VAV systems. In a few cases, condenser heat recovery equipment and water storage tanks were added. Also, four out of eleven buildings in the sample adopted dead band controls. Outside air quantities were reduced on the average by 20%. For the most part, in the original designs excess heat from lights was removed by using return air troffers and economizers. Also, there was a tendency to replace constant cooling auxiliaries with variable auxiliaries.

In small offices the tendency was to utilize heat pump/passive system combinations. In most cases the dead band ranges were significantly increased. Economizers were added only in a few cases. Return air troffers were not as prevalent as in large offices, and buildings that did not have them in the original design made no further additions. Exhaust air recovery was by and large absent in all small office redesigns.

FIGURE 1.1. Small and Large Offices

FIGURE 1.2. Frequency of Strategies - Offices

FIGURE 1.3. Conduction - Offices

FIGURE 1.4. Solar Control - Offices

FIGURE 1.5. Lighting - Offices

FIGURE 1.6. Primary and Secondary Systems - Offices

FIGURE 1.7. HVAC Set Points - Offices

FIGURE 1.8. Equipment Efficiency - Offices

FIGURE 1.9 A&B. Miscellaneous Energy Parameters

FIGURE 1.9 C. Miscellaneous Energy Parameters

SPACE USE: PERCENT OF GROSS AREA

FIGURE 1.10. Space Use and Cost Change - Offices

KEY ENERGY PARAMETERS
EXTRACTIONS FROM COMPUTER STORED DATA

P.A. NO.	BLDG NO.	FLOOR AREA		ORIENT. DEG. FROM NORTH	MAJOR ORIENT.	WINTER INF. (ACH)	WALL BELOW GRADE	U-VALUES				BLDG MASS (LB/SF)			BLDG COLOR	
		GROSS	NET					WALL	ROOF	GLASS	COMPOSITE	WALL	ROOF	FLOOR	WALL	ROOF
1	60	8140.	7987.	35	E-W	0.35	0.	0.10	0.11	0.60	0.14	65.0	10.0	75.0	M	M
	560	8438.	7429.	0	E-W	0.25	12.	0.06	0.04	0.53	0.10	117.6	47.0	75.0	M	L
2	6A	24900.	16190.	0	N-S	0.40	0.	0.06	0.05	0.57	0.10	50.0	30.0	80.0	M	M
	56A	25000.	16280.	0	E-W	0.30	0.	0.05	0.05	0.38	0.07	50.0	30.0	80.0	M	M
3	62	7180.	6649.	0	N-S	0.60	45.	0.07	0.10	0.58	0.14	35.6	9.3	30.0	D	D
	562	7495.	6471.	0		0.60	52.	0.06	0.03	0.57	0.12	66.0	10.0	30.0	L	L
4	84	28900.	28500.	0	E-W	0.80	5.	0.08	0.07	0.54	0.15	54.0	25.0	40.0	A	M
	584	29000.	26800.	0	E-W	0.80	22.	0.07	0.03	0.54	0.10	76.7	52.0	40.0	L	L
6	31	11000.	10999.	14		0.60	0.	0.12	0.11	0.60	0.17	75.3	10.0	50.0	D	D
	533	11000.	8993.	14		0.60	0.	0.07	0.04	0.60	0.09	81.7	33.0	50.0	D	D
7	34	52352.	46163.	324	N-S	0.50	17.	0.25	0.04	0.50	0.20	59.8	11.1	42.0	M	D
	534	52496.	44950.	10	E-W	0.25	11.	0.04	0.04	0.50	0.09	108.7	12.0	42.0	M	M
8	111	3080.	2805.	0	N-S	0.50	0.	0.07	0.13	1.13	0.16	9.0	7.0	80.0	M	D
	631	3822.	3012.	0	N-S	0.50	24.	0.08	0.03	0.60	0.08	140.0	7.0	70.0	M	L
9	111	21100.	20755.	14		0.20	0.	0.08	0.10	0.54	0.15	6.1	10.0	34.0	L	M
	611	22700.	20032.	0		0.20	4.	0.07	0.05	0.53	0.11	41.4	12.0	34.0	L	M
10	74	5505.	5446.	0		0.90	0.	0.09	0.04	1.04	0.14	40.7	13.0	83.0	D	D
	574	5520.	5482.	0		0.90	0.	0.09	0.04	0.56	0.09	41.6	13.0	83.0	L	L
11	151	16064.	14400.	0		0.50	0.	0.20	0.05	1.10	0.42	59.9	5.0	15.0	M	L
	651	20352.	17280.	0	E-W	0.50	0.	0.08	0.05	0.65	0.24	60.7	5.0	15.0	L	L
MEAN ORIGINAL DESIGN		17822.	15989.	39.		0.54	7.	0.12	0.08	0.72	0.18	45.4	13.0	52.9		
MEAN REDSIGN		18582.	15672.	2.		0.49	13.	0.07	0.04	0.55	0.11	78.4	22.1	51.9		

NOTE: DATA FOR BLDG #5 - 4/504 NOT AVAILABLE

P.A. NO.	BLDG NO.	BLDG GLASS AREAS				SKYLIGHT AREA (SROOF)	GLASS SHADE COEFFICIENT				EXT SHADE	PROCESS LOADS			
		SQ. FT	ENVELOPE	SOUTH	NORTH		SOUTH	NORTH	EAST	WEST		GENERAL Kd/SF	BTUH/SF	SPECIAL Kd/SF	BTUH/SF
1	60	627.	10.	20.	68.	0.	0.55	0.55	0.55	0.55	YES	0.000	0.0	0.000	0.0
	560	985.	15.	56.	0.	0.	0.87	0.00	0.87	0.87	YES	0.000	0.0	0.000	0.0
2	66	1727.	15.	33.	6.	0.	0.58	0.58	0.58	0.58	YES	0.001	0.0	0.000	0.0
	566	1260.	11.	52.	8.	0.	0.58	0.58	0.58	0.58	YES	0.001	0.0	0.000	0.0
3	69	709.	21.	31.	6.	0.	0.56	0.56	0.56	0.56	YES	0.000	0.0	0.000	0.0
	569	947.	31.	70.	0.	0.	0.79	0.00	0.40	0.40	YES	0.000	0.0	0.000	0.0
4	84	3355.	22.	37.	46.	0.	0.71	0.71	0.71	0.71		0.001	0.0	0.000	0.0
	584	2330.	16.	97.	0.	0.	0.71	0.00	0.53	0.53		0.001	0.0	0.000	0.0
6	33	1336.	18.	0.	83.	0.	0.00	0.88	0.88	0.00	YES	0.001	0.0	0.015	0.0
	533	878.	12.	0.	83.	0.	0.00	0.88	0.88	0.00	YES	0.001	0.0	0.016	0.0
7	39	5146.	28.	15.	13.	0.	0.69	0.69	0.69	0.69	YES	0.001	0.0	0.000	0.0
	539	3732.	18.	48.	29.	0.	0.69	0.69	0.69	0.69	YES	0.001	0.0	0.000	0.0
8	131	340.	11.	27.	9.	0.	0.50	0.50	0.50	0.50	YES	0.000	0.0	0.000	0.0
	631	263.	13.	37.	8.	0.	0.54	0.54	0.54	0.54	YES	0.000	0.0	0.000	0.0
9	113	3403.	44.	37.	28.	0.	0.57	0.57	0.57	0.57	YES	0.001	0.0	0.000	0.0
	613	2332.	23.	41.	44.	0.	0.23	0.23	0.23	0.23	YES	0.001	0.0	0.000	0.0
10	74	683.	19.	32.	32.	0.	0.92	0.92	0.92	0.89	YES	0.000	0.0	0.005	0.0
	574	474.	8.	22.	70.	0.	0.58	0.58	0.58	0.00	YES	0.000	0.0	0.005	0.0
11	151	5052.	46.	30.	30.	0.	0.80	0.80	0.80	0.77	YES	0.000	0.0	0.000	0.0
	651	4872.	41.	52.	48.	0.	0.69	0.58	0.00	0.00	YES	0.000	0.0	0.000	0.0
MEAN ORIGINAL DESIGN		2258.	23.	26.	32.	0.	0.65	0.68	0.68	0.65		0.000	0.0	0.002	0.0
MEAN REDFSIGN		1807.	19.	48.	29.	0.	0.63	0.58	0.59	0.55		0.000	0.0	0.002	0.0

NOTE: DATA FOR BLDG #5 - 4/504 NOT AVAILABLE

NEPS PHASE II KEY DATA BASE PARAMETER: SMALL OFFICES
LIGHTING SYSTEM

04-JAN-93
PAGE 3

P.A. BLDG NO.	BLDG NO.	WATTS PER S.F.	ILLUM. LEVEL	LAMP TYPE (% TOTAL FLOOR AREA)								CONTROL TYPE (% TOTAL FLOOR AREA)							
				TC	TH	F	HC	HH	HPS	LPS	U	OKR	St	LV	CFIR	PH	CEM	TC	U
1	60	1.9	49.	75.	0.	25.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	560	1.4	40.	10.	0.	78.	17.	0.	0.	0.	0.	0.	96.	0.	0.	0.	0.	4.	0.
2	66	2.7	55.	11.	0.	89.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	586	1.3	45.	2.	0.	98.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
3	69	2.2	45.	30.	0.	70.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	569	1.2	8.	0.	0.	100.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
4	84	2.7	78.	4.	0.	96.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	584	1.7	18.	2.	0.	98.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
6	33	2.8	61.	35.	0.	65.	0.	0.	0.	0.	0.	48.	52.	0.	0.	0.	0.	0.	0.
	533	2.5	52.	34.	0.	66.	0.	0.	0.	0.	0.	38.	62.	0.	0.	0.	0.	0.	0.
7	39	2.0	33.	0.	0.	100.	0.	0.	0.	0.	0.	56.	44.	0.	0.	0.	0.	0.	0.
	539	0.8	47.	0.	0.	100.	0.	0.	0.	0.	0.	47.	53.	0.	0.	0.	0.	0.	0.
8	131	3.8	55.	47.	0.	58.	0.	0.	0.	0.	0.	49.	51.	0.	0.	0.	0.	0.	0.
	531	1.6	47.	9.	0.	91.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
9	113	2.9	49.	19.	0.	81.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	613	1.4	31.	11.	0.	89.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
10	74	4.3	95.	12.	0.	88.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	574	2.5	62.	7.	0.	93.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
11	151	2.8	35.	0.	0.	100.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	551	2.3	35.	0.	0.	100.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
MEAN ORIGINAL DESIGN		2.8	67.	23.	0.	77.	0.	0.	0.	0.	0.	15.	85.	0.	0.	0.	0.	0.	0.
MEAN REDESIGN		1.7	41.	7.	0.	91.	1.	0.	0.	0.	0.	8.	91.	0.	0.	0.	0.	0.	0.

NOTE: DATA FOR BLDG 85 - 4/504 NOT AVAILABLE

DEFS PHASE II KEY DATA BASE PARAMETER: SMALL OFFICES
SECONDARY SYSTEM

04-JAN-83
PAGE 4

P.A. NO.	BLDG NO.	SYSTEM ID		T-STAT SET PT.		COOL HEAT	DAY HEAT	NIGHT HEAT	DEAD HAND	W/LIGHT TO PA	USCHG CTRL	EXHAUST AIR HEAT RECOVERY VENT APPR	SUPPLY CFM/SF PER,INT.		CFM PER HP	OUTSIDE AIR			ECON TYPE	
		INT	PER	COOL	DAY								%	CFM		CFM/PER				
1	60	15	15	75.	70.	65.	YES	0.	20.			0.	0.	0.88	0.85	3907.	10.	715.	5.	ENTH
	560	15	15	75.	67.	67.	YES	13.	20.			0.	0.	0.62	0.14	3200.	10.	480.	6.	ENTH
2	66	5	3	78.	70.	65.	YES	0.	0.	NO		0.	0.	0.96	0.79	1541.	11.	1680.	28.	
	566	5	5	78.	70.	60.	YES	5.	0.	NO		0.	0.	0.91	1.26	3109.	9.	1335.	22.	ENTH
3	69	7	3	78.	70.	70.	YES	0.	0.			0.	0.	0.97	0.13	3868.	10.	453.	15.	
	569	0	15	78.	70.	65.	YES	5.	0.			0.	0.	0.70	0.00	2162.	5.	200.	6.	
4	84	15	15	78.	75.	75.	YES	4.	20.			100.	69.	0.80	0.35	3950.	10.	1778.	14.	
	584	15	15	78.	75.	75.	YES	6.	20.			100.	69.	1.17	0.44	5136.	10.	2311.	14.	65.
6	33	3	3	78.	70.	70.	YES	0.	0.			0.	0.	1.15	1.12	2905.	23.	2866.	17.	
	533	3	3	78.	70.	70.	YES	0.	0.			0.	0.	1.17	1.44	1683.	17.	1878.	11.	
7	39	14	14	78.	72.	72.	YES	0.	0.			0.	0.	1.22	1.06	1748.	12.	6293.	16.	
	539	15	15	78.	68.	68.	YES	6.	30.			0.	0.	0.73	0.74	2200.	8.	2640.	7.	
8	131	0	3	75.	70.	55.	YES	0.	30.			0.	0.	1.32	0.00	1850.	10.	370.	21.	
	631	0	15	78.	68.	55.	YES	10.	50.			0.	0.	1.05	0.00	2442.	10.	318.	18.	60.
9	113	0	13	75.	72.	60.	YES	0.	50.			0.	0.	1.23	0.00	589.	8.	2040.	17.	
	613	15	15	78.	72.	65.	YES	10.	31.			0.	0.	0.70	0.65	1579.	10.	1370.	10.	
10	74	0	2	75.	70.	0.	NO	0.	0.			0.	0.	1.56	0.00	1479.	12.	1074.	19.	60.
	574	0	5	75.	70.	0.	NO	5.	0.	NO		0.	0.	0.70	0.00	1580.	22.	845.	21.	ENTH
11	151	3	3	77.	70.	60.	YES	0.	0.			0.	0.	1.69	0.52	2400.	5.	1080.	14.	
	651	3	3	77.	70.	55.	NO	7.	0.			0.	0.	1.09	0.60	1600.	6.	1008.	10.	
MEAN ORIGINAL DESIGN				77.	71.	59.		4.	30.			10.	7.	1.18	0.69	2424.	11.	1835.	16.	
MEAN REDESIGN				77.	70.	58.		7.	30.			10.	7.	0.88	0.75	2469.	11.	1239.	13.	

NOTE: DATA FOR BLDG #5 - 4/504 NOT AVAILABLE

PEPS PHASE II KEY DATA BASE PARAMETER: SMALL OFFICES
PRIMARY SYSTEM

06-JAN-83
PAGE 5

P.A. NO.	REC. NO.	CHILLER COOLING COP	HEATING EFF.	HEAT RECOVERY	HEAT PUMP TYPE	HP HEATING COP	COOLING FUEL TYPE	BOT. WATER STORAGE (BTU/BTU CAP)	ANX. KW COOLING VAR.	ANX. KW COOLING CONST.	ANX. KW HEATING VAR.	ANX. KW HEATING CONST.	S.F. PER TON	HEATING BTU PER SF
1	60 560	2.5 2.2	0.0 0.0		11	0.0 2.9	E E	0. 2665600.	0. 0.	0. 2.	0. 0.	0. 0.	465. 0.	0. 0.
2	66 566	2.6 3.5	0.8 0.0	YFS		0.0 0.0	E E	0. 1850000.	0. 2.	8. 5.	1. 0.	4. 0.	367. 495.	49. 0.
3	69 569	1.9 2.1	0.8 0.7		11	0.0 3.0	E E	0. 7.	0. 1.	0. 4.	0. 0.	0. 1.	856. 0.	51. 11.
4	84 504	2.7 2.4	1.0 1.0		11 11	2.7 2.8	E E	0. 128.	3. 3.	9. 9.	0. 0.	0. 0.	0. 0.	1. 1.
6	33 534	2.5 2.9	0.8 0.7			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	341. 315.	69. 33.
7	70 530	2.1 2.4	1.0 0.0		11	0.0 2.7	E E	0. 0.	0. 20.	0. 0.	0. 0.	0. 0.	310. 0.	50. 0.
8	131 631	1.9 1.9	0.9 0.0			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	270. 439.	31. 0.
9	113 613	2.7 2.1	1.0 0.0		11	0.0 2.8	E E	0. 126000.	0. 1.	6. 4.	0. 0.	0. 0.	332. 0.	13. 0.
10	74 574	1.2 6.1	0.9 1.0			0.0 0.0	E E	0. 0.	0. 2.	0. 0.	0. 0.	0. 0.	264. 374.	68. 19.
11	151 651	2.1 2.1	0.8 0.8			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	272. 461.	85. 56.
MEAN ORIGINAL DESIGN		2.7	0.9	0		2.7		0.	0.	2.	0.	0.	388.	44.
MEAN REDESIGN		2.8	0.9	1		2.8		930347.	3.	2.	0.	0.	417.	12.

NOTE: DATA FOR BLDC #5 - 4/504 NOT AVAILABLE

APPS PHASE 11 KEY DATA BASE PARAMETER: LARGE OFFICES
ENVELOPE

04-JAN-83
PAGE 1

P.A. NO.	BLDG NO.	FLOOR AREA		ORIENT. DEG. FRM NORTH	MAJOR ORIENT.	WINTER INF. (ACH)	WALL BELOW GRADE	U-VALUES				BLDG MASS (LB/FF)			BLDG COLOR	
		GROSS	NET					WALL	POOR	GLASS	COMPOSITE	WALL	ROOF	FLOOR	WALL	ROOF
12	54	408200.	362100.	0		1.00	8.	0.17	0.10	0.60	0.28	23.1	60.0	60.0	L	M
	554	393382.	337200.	0		1.00	22.	0.08	0.08	0.56	0.22	50.0	125.0	125.0	L	L
13	80	89895.	68456.	0	E-W	0.75	0.	0.14	0.10	0.55	0.13	79.7	71.6	131.3	M	M
	580	98900.	69116.	330	E-W	1.00	0.	0.14	0.05	0.55	0.10	84.6	71.6	132.0	M	M
14	5	47500.	44200.	16	N-S	0.50	9.	0.18	0.12	1.13	0.33	63.0	8.0	63.0	L	M
	505	50490.	46940.	0	E-W	0.50	8.	0.05	0.08	0.65	0.12	63.0	8.0	63.0	L	M
15	32	190250.	161100.	7		0.00	16.	0.10	0.12	0.55	0.17	35.9	5.0	50.0	L	L
	532	189700.	159600.	0	E-W	0.11	6.	0.08	0.05	0.55	0.12	50.0	100.0	50.0	L	L
16	89	859000.	735738.	0		0.04	22.	0.12	0.15	0.55	0.30	6.5	160.0	160.0	L	M
	589	859000.	514008.	0		0.03	2.	0.10	0.08	0.49	0.26	10.0	160.0	160.0	L	M
17	125	101754.	100736.	328		0.35	0.	0.12	0.07	0.54	0.17	50.0	40.0	50.0	M	M
	625	100000.	97000.	328		0.30	0.	0.12	0.07	0.54	0.17	50.0	40.0	50.0	M	M
18	25	94100.	84060.	316	N-S	0.60	5.	0.08	0.09	0.53	0.12	63.8	35.0	48.0	L	M
	525	93900.	88480.	0	E-W	0.60	16.	0.07	0.05	0.57	0.12	62.5	39.0	48.0	L	M
19	22	87333.	64074.	357	E-W	1.00	6.	0.20	0.12	0.55	0.27	69.5	67.0	68.0	M	M
	522	87333.	64074.	357	E-W	0.50	0.	0.20	0.12	0.55	0.27	69.4	67.0	68.0	M	M
20	29	98000.	90542.	360	N-S	0.15	0.	0.15	0.15	0.53	0.30	113.0	79.0	72.0	L	L
	529	103000.	91000.	360	E-W	0.15	0.	0.05	0.09	0.53	0.20	102.0	79.0	72.0	L	L
21	118	104300.	84740.	0		0.00	9.	0.23	0.08	1.10	0.37	132.8	70.0	60.0	M	M
	618	109750.	93810.	0	E-W	0.00	3.	0.11	0.05	0.56	0.15	125.8	70.0	60.0	M	M
22	154	60100.	52362.	0		0.00	26.	0.13	0.10	1.17	0.42	10.5	80.0	75.0	M	M
	654	60110.	47780.	0		0.15	37.	0.09	0.05	0.96	0.47	6.5	80.0	75.0	L	L
MEAN ORIGINAL DESIGN		194585.167826.		126.		0.40	9.	0.14	0.11	0.71	0.26	58.9	61.4	76.1		
MEAN REDESIGN		195051.146273.		125.		0.39	9.	0.10	0.07	0.59	0.20	61.3	76.3	82.1		

BEPS PHASE II KEY DATA BASE PARAMETER: LARGE OFFICES
ENVELOPE

04-JAN-83
PAGE 2

P.A. NO.	BLDG NO.	BLDG GLASS AREAS				SKYLIGHT AREA (%ROOF)	GLASS SHADE COEFFICIENT				EXT SHADE	PROCESS LOADS			
		50 FT	ELEV	%SOUTH	%NORTH		SOUTH	NORTH	EAST	WEST		GENERAL Kk/SF	GENERAL BTUH/SF	SPECIAL Kk/SF	SPECIAL BTUH/SF
12	54	54235.	43.	23.	19.	0.	0.40	0.39	0.43	0.39	YES	0.001	0.0	0.001	0.0
	554	41995.	38.	20.	24.	2.	0.24	0.28	0.28	0.20	YES	0.001	0.0	0.001	0.0
13	80	2374.	15.	0.	97.	0.	0.00	0.57	0.00	0.57		0.000	0.0	0.002	1.3
	580	2830.	19.	50.	50.	1.	0.57	0.57	0.00	0.00	YES	0.000	0.0	0.002	1.2
14	5	6408.	36.	20.	17.	0.	0.64	0.64	0.64	0.64	YES	0.001	0.0	0.000	0.0
	505	3500.	19.	49.	51.	0.	0.39	0.39	0.00	0.00	YES	0.001	0.0	0.000	0.0
15	32	17800.	35.	39.	34.	0.	0.56	0.56	0.56	0.56	YES	0.000	2.1	0.003	0.0
	512	10900.	24.	36.	17.	10.	0.56	0.56	0.24	0.24	YES	0.001	0.0	0.003	0.0
16	89	106254.	48.	23.	23.	0.	0.44	0.44	0.44	0.46		0.000	0.0	0.001	0.0
	589	100825.	49.	23.	23.	0.	0.24	0.25	0.24	0.28		0.000	0.0	0.001	0.0
17	175	9567.	23.	37.	37.	0.	0.38	0.38	0.38	0.38	YES	0.000	0.0	0.001	0.0
	625	9070.	22.	45.	16.	0.	0.38	0.38	0.38	0.38	YES	0.000	0.0	0.001	0.0
18	25	4170.	12.	31.	3.	0.	0.25	0.39	0.39	0.39		0.001	0.0	0.000	0.0
	525	6263.	19.	51.	0.	0.	0.66	0.00	0.66	0.66	YES	0.001	0.0	0.000	0.0
19	22	14783.	43.	36.	29.	0.	0.60	0.60	0.60	0.60		0.001	0.0	0.000	0.0
	522	13112.	43.	36.	33.	0.	0.30	0.60	0.30	0.30	YES	0.001	0.0	0.000	0.0
20	29	23004.	54.	19.	19.	0.	0.49	0.49	0.49	0.49	YES	0.000	0.0	0.000	0.0
	529	17200.	40.	32.	32.	0.	0.49	0.49	0.49	0.49	YES	0.000	0.0	0.000	0.0
21	118	11538.	30.	47.	43.	0.	0.21	0.67	0.40	0.40		0.001	0.0	0.000	2.0
	518	9754.	17.	43.	53.	0.	0.20	0.67	0.40	0.40	YES	0.001	0.0	0.000	1.9
22	154	11076.	47.	27.	29.	0.	0.57	0.58	0.57	0.56	YES	0.001	0.0	0.000	0.0
	654	18640.	63.	27.	52.	0.	0.76	0.54	0.76	0.76	YES	0.001	0.0	0.000	0.0

MEAN ORIGINAL DESIGN	23746.	35.	27.	32.	0.	0.45	0.52	0.49	0.49			0.001	0.2	0.001	0.3
MEAN REDESIGN	21281.	32.	37.	32.	1.	0.44	0.47	0.42	0.41			0.001	0.0	0.001	0.3

PEPS PHASE II KEY DATA BASE PARAMETER: LARGE OFFICES
LIGHTING SYSTEM

04-JAN-83
PAGE 3

F.A. NO.	BLDG NO.	WATTS PER S.F.	ILLUM. LEVEL	LAMP TYPE (PERCENT TOTAL FLOOR AREA)								CONTROL TYPE (% TOTAL FLOOR AREA)							
				THC	TH	F	HC	WH	HPS	LPS	0	MRP	SN	LV	CPTR	PH	DIM	IC	0
12	54 554	4.4 2.2	79. 62.	13. 6.	0. 0.	86. 94.	0. 0.	0. 0.	0. 0.	0. 0.	0.	17. 0.	0. 0.	0. 8.	78. 63.	0. 28.	5. 0.	0. 0.	0.
13	80 540	2.3 1.0	65. 39.	14. 0.	0. 0.	70. 78.	13. 0.	0. 0.	0. 22.	0. 0.	0.	76. 0.	10. 72.	0. 0.	0. 0.	0. 28.	7. 0.	4. 0.	0.
14	5 505	3.6 1.8	101. 85.	0. 0.	0. 0.	100. 100.	0. 0.	0. 0.	0. 0.	0. 0.	0.	0. 0.	100. 100.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0.
15	32 532	2.2 1.0	62. 40.	2. 9.	0. 0.	98. 91.	0. 0.	0. 0.	0. 0.	0. 0.	0.	0. 0.	100. 55.	0. 0.	0. 0.	0. 44.	0. 1.	0. 0.	0.
16	89 589	2.4 1.5	51. 68.	15. 0.	1. 1.	85. 96.	0. 0.	0. 0.	0. 3.	0. 0.	0.	38. 9.	62. 56.	0. 0.	0. 0.	0. 34.	1. 0.	0. 0.	0.
17	125 625	2.6 1.5	100. 69.	5. 5.	0. 0.	95. 95.	0. 0.	0. 0.	0. 0.	0. 0.	0.	0. 0.	2. 2.	0. 0.	92. 56.	0. 36.	5. 5.	0. 0.	0.
18	25 525	2.2 1.7	82. 57.	0. 0.	0. 0.	100. 100.	0. 0.	0. 0.	0. 0.	0. 0.	0.	9. 0.	9. 100.	82. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0.
19	22 522	3.1 1.8	90. 55.	0. 0.	0. 0.	100. 100.	0. 0.	0. 0.	0. 0.	0. 0.	0.	0. 0.	100. 100.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0.
20	29 529	2.2 2.1	70. 69.	1. 1.	0. 0.	98. 98.	0. 0.	0. 0.	0. 0.	0. 0.	0.	0. 0.	99. 62.	0. 0.	0. 0.	0. 37.	0. 0.	0. 0.	0.
21	118 618	2.6 2.0	79. 58.	11. 5.	0. 0.	74. 81.	15. 14.	0. 0.	0. 0.	0. 0.	0.	4. 7.	96. 36.	0. 0.	0. 0.	0. 57.	0. 0.	0. 0.	0.
22	154 654	1.4 2.1	44. 65.	20. 0.	0. 0.	80. 100.	0. 0.	0. 0.	0. 0.	0. 0.	0.	0. 0.	100. 57.	0. 0.	0. 0.	0. 43.	0. 0.	0. 0.	0.
MEAN ORIGINAL DESIGN				2.6	74.	7.	0.	90.	3.	0.	0.	13.	62.	7.	15.	0.	2.	0.	0.
MEAN REDESIGN				1.7	61.	2.	0.	94.	1.	0.	2.	1.	58.	1.	11.	28.	1.	0.	0.

REPS PHASE II KEY DATA BASE PARAMETER: LARGE OFFICES
SECONDARY SYSTEM

04-JAN-83
PAGE 4

P.A. NO.	BLDG NO.	SYSTEM ID		I-STAT		SET PT.		DEAD HAND	HEAT TO HA	DSCHG TEMP CTRL	EXHAUST AIR HEAT RECOVERY %VENT %EFF	SUPPLY		CFM PER RHP	OUTSIDE AIR			ECOH TYPE
		INT	PER	COOL	DAY	NIGHT	NIGHT					CFM/RF	PER,INT.		%	CFM	CFM/PER	
12	54	4	4	77.	72.	72.	YES	0.	60.	NO	0.	0.94	0.74	471.	15.	45185.	23.	ENTH
	554	4	15	78.	72.	60.	YES	0.	60.	NO	42.	15.	1.16	0.38	797.	6.	15829.	
13	80	5	7	78.	70.	60.	YES	0.	20.	NO	51.	70.	1.54	1.07	1227.	19.	17558.	56.
	580	5	3	78.	70.	60.	YES	6.	30.	NO	0.	0.	0.68	0.49	1348.	10.	4420.	60.
14	5	3	15	75.	75.	65.	YES	0.	25.		0.	0.	1.73	1.29	1272.	12.	8560.	19.
	505	3	15	78.	64.	60.	YES	0.	25.		0.	0.	1.24	1.31	1337.	9.	5326.	24.
15	32	4	5	78.	72.	55.	YES	0.	20.	NO	0.	0.	1.23	0.92	791.	15.	26578.	55.
	512	4	5	78.	72.	55.	YES	0.	0.	NO	0.	0.	0.87	0.70	708.	14.	18623.	60.
16	82	6	6	76.	75.	68.	YES	0.	30.		0.	0.	2.81	0.68	712.	19.	187435.	47.
	589	6	5	76.	72.	65.	YES	0.	30.	NO	76.	50.	1.73	0.63	613.	12.	66121.	13.
17	125	15	15	78.	72.	0.	NO	6.	50.		0.	0.	1.02	0.47	6628.	13.	9699.	50.
	625	5	5	78.	72.	0.	NO	0.	80.	NO	4.	60.	0.99	0.83	1221.	27.	25174.	59.
18	25	3	9	78.	72.	0.	NO	0.	20.		0.	0.	1.20	0.83	1243.	20.	16950.	45.
	525	5	5	78.	68.	0.	NO	10.	15.	NO	0.	0.	0.96	0.65	1584.	7.	4551.	ENTH
19	22	5	5	75.	70.	60.	YES	0.	25.	NO	0.	0.	1.94	0.83	537.	15.	13785.	23.
	522	5	5	75.	70.	60.	YES	4.	25.	NO	0.	0.	1.46	0.63	405.	15.	10377.	ENTH
20	29	3	2	76.	72.	60.	YES	0.	50.		0.	0.	2.06	0.86	1257.	10.	13278.	15.
	529	3	12	78.	70.	60.	YES	8.	50.		0.	0.	1.20	0.60	1240.	10.	8068.	57.
21	118	5	5	76.	70.	0.	NO	0.	40.	NO	0.	0.	1.63	0.69	723.	10.	9760.	20.
	618	4	5	78.	68.	0.	NO	0.	40.	NO	0.	0.	0.86	0.50	440.	9.	6251.	13.
22	154	5	5	78.	68.	0.	NO	10.	65.	NO	0.	0.	1.48	0.97	828.	14.	9663.	65.
	654	15	15	75.	70.	0.	NO	5.	0.		0.	0.	1.56	0.74	2369.	11.	6827.	20.
MEAN ORIGINAL DESIGN				77.	72.	40.		8.	37.		5.	6.	1.60	0.85	1426.	15.	32586.	30.
MEAN REDESIGN				77.	70.	38.		7.	39.		11.	11.	1.16	0.68	1096.	12.	15597.	17.

DEFS PHASE II KEY DATA BASE PARAMETER: LARGE OFFICES
PRIMARY SYSTEM

06-JAN-83
PAGE 5

P.A. NO.	BLDG. NO.	CHILLER COOLING COP	HEATING EFF.	HEAT RECOVERY	HEAT PUMP TYPE	HP HEATING COP	COOLING FUEL TYPE	HOT WATER STORAGE (BTU/HTU CAP)	AUX. KW COOLING VAR.	CONST	AUX. KW HEATING VAR.	CONST	S.F. PER TON	HEATING BTU PER SF
12	54 554	4.3 2.4	1.0 1.0	YES YES		0.0 2.7	I E	0. 131.	176. 50.	53. 59.	0. 0.	0. 0.	321. 838.	1. 8.
13	80 580	3.5 4.4	1.0 0.7			0.0 0.0	E E	0. 0.	0. 2.	11. 0.	0. 0.	0. 0.	350. 976.	75. 11.
14	5 505	2.3 3.0	0.7 0.7		11 11	3.0 3.6	E E	0. 0.	6. 3.	22. 12.	0. 0.	0. 0.	525. 765.	20. 8.
15	32 532	3.8 3.8	0.8 0.8			0.0 0.0	E E	0. 0.	55. 37.	15. 10.	29. 25.	0. 0.	347. 550.	54. 51.
16	80 580	1.0 4.1	1.0 0.0	YES		0.0 0.0	I E	0. 24000000.	65. 30.	0. 0.	0. 0.	0. 0.	206. 262.	23. 0.
17	125 625	2.4 5.0	0.0 0.0	YES	11	3.3 0.0	E E	366000. 300000.	7. 15.	315. 22.	0. 0.	0. 0.	0. 630.	0. 0.
18	25 525	4.3 4.3	1.0 0.0	YES		0.0 0.0	E E	0. 1400000.	9. 7.	22. 17.	0. 0.	9. 0.	480. 681.	21. 0.
19	22 522	3.6 3.6	1.0 0.8			0.0 0.0	E E	0. 0.	22. 17.	14. 12.	0. 0.	0. 0.	352. 461.	27. 13.
20	22 520	4.1 4.8	0.9 0.8			0.0 0.0	E E	0. 0.	24. 20.	9. 7.	3. 3.	0. 0.	312. 373.	74. 66.
21	118 618	3.9 4.4	0.9 0.0	YES		0.0 0.0	E E	0. 470000.	44. 39.	44. 36.	4. 0.	0. 0.	242. 419.	11. 0.
22	154 654	2.6 2.6	0.8 0.0		11	0.0 2.9	E E	0. 182600.	0. 14.	0. 15.	4. 0.	0. 0.	455. 0.	26. 0.
MEAN ORIGINAL DESIGN		3.3	0.9	1		3.2		366000.	37.	46.	4.	1.	359.	30.
MEAN REDESIGN		3.9	0.8	5		3.1		4392122	21.	17.	3.	0.	595.	14.

SUMMARY OF SECTION CONTENTS

2. Retail

a. Article: "Energy for Sales"

b. Building Type Analysis

2.1 Energy Characteristics of Retail Buildings

2.1.1 General Overview of Issues and Buildings

2.1.2 Usage Profile

2.1.3 Typical End Use Percentages

2.2 Building Sample Issues

2.3 Analysis of Redesign Strategies

2.4 Fulfillment of the Technical Potential

c. Key Energy Parameters - Graphic Presentations

d. Key Energy Parameters - Extractions from Computer Stored Data

Energy for sales

This month's energy series article* focuses on retail buildings. After reorganizing the original data, the research team discovered both general strategies of great promise and design options of importance only to certain types of retail stores.

Contributors: A number of individuals and organizations have contributed to the development of this article. Principal researchers: Joseph J. Deringer, President, Gilford, Deringer and Company; Harry P. Misuriello, Principal, W.S. Fleming & Associates.

Researchers: James Binkley, Chief, Architectural and Engineering Systems Branch, DOE; John Stoops, Project Manager, and Ray Reilly, Program Manager, Battelle Pacific Northwest Laboratories; John H. Cable, Principal, The Ehrenkrantz Group; Roger Easley, Consultant to Battelle; Santiago Moreno, Mike Gilford, and Richard Meilan, with Gilford, Deringer and Company.

The 19 redesigned retail buildings featured in this article differ widely in terms of size, merchandise sold, mix of functional spaces, and even their role in the community. Included are buildings ranging from a 7000-sq-ft chain bookstore to a 671,000-sq-ft regional shopping center.

Early in the research effort, stores and shopping centers were proposed as retail categories for promulgating the BEPS design energy budgets; i.e., "mean" levels of aggregate building energy performance (P/A, April 1980, p. 92). It became apparent that these two classifications would not present the redesign strategies in sufficient detail to convey their diversity. For this article, therefore, we have expanded the categories as follows, using size and tenant criteria established by the Urban Land Institute and the AIA: *Regional Centers* with average total area of 580,000 sq ft, with an enclosed mall area and one or two major department stores, each typically not less than 100,000 sq ft. *Neighborhood Centers* of 27,000 to 96,000 sq ft, containing a supermarket as the principal tenant. *Department Stores*—usually stand-alone buildings with single tenant occupancy. In the redesign sample, three were also "anchor stores" for regional malls. *Strip Shopping Centers* are buildings that have no principal tenant but are rather a collection of leased shops.

The 26 percent energy reduction achieved by the retail redesign teams over their original designs is significant, but not as substantial as in other building types. As explained later, a wide range of constraints influenced each of the retail redesigns to some extent.

How is the energy used?

The merchandising mission of these buildings places design emphasis on the building's interior systems more than on its exterior components. The design of lighting systems to promote merchandising has different criteria from that

for increasing worker productivity in office buildings (P/A, June 1982, p. 109).

Retail buildings, however, share with office buildings the need for "universal" space design. Shops in regional, neighborhood, and strip shopping centers must accommodate energy-consuming tenants as diverse as a jewelry store, a bakery, and a record shop. Tenant mix and amount of leased square footage may also vary from month to month. These factors influence energy consumption but are difficult to predict or control. Retail buildings operate longer hours than most others. A six- or seven-day-a-week operation for 10 to 12 hours a day is not uncommon. Internal gains from equipment are minimal in most retail operations except for food-related operations, such as bakeries and carry-outs. Nevertheless, they are generally considered to be "load dominated," primarily due to high uniform lighting loads and to high occupant density. As a result, retail energy use is almost "steady state" at given weather conditions and is not subject to time-related load swings such as those found in office buildings.

Design considerations

The form and envelope configuration of retail buildings is frequently dictated by functional space requirements and site constraints. Often there is little flexibility to adjust building orientation for energy concerns. Also, façade treatment may be of secondary importance in malls and department stores where interior merchandising is preferred.

Lighting systems are operated for long hours at higher lighting levels than in other building types, and there is a significant need for incandescent display lighting. With lighting about 35 percent of total annual retail energy usage, it is no surprise that much of the redesign effort was concentrated on this area. But the designer's influence can be limited. Tenants often furnish their own lighting systems. Parking lot lighting is also significant but was not studied in redesign experiment.

* A complete description of this series can be found in the April 1982 issue of P/A, pages 110-115.

STRATEGIES: Reflective roof; Ambient lighting levels reduced; 50% illumination reduction during restocking and clean-up periods; Energy conserving fluorescents; Packaged constant volume units replaced by central VAV system; Air from sales area exhausted through stockrooms, receiving areas and auto center; Unit heaters in auto center replaced with radiant heaters.

4 DEPARTMENT STORE: PORTLAND, OR

STRATEGIES: Reflective roof; Daylighting of mall area, on-off photocell controls; High efficiency vane-axial fans; Low pressure VAV boxes; Return air troffers.

8 MALL FOR REGIONAL CENTER: NEWARK, NJ

STRATEGIES: Wall and roof insulation almost tripled; Reduced exposed area; Double glazing; Incandescent lamps replaced by fluorescents; Double switching; Air to air heat pumps; Enthalpy economizer cycle; Deadband controls; Exhaust air heat recovery.

11 NEIGHBORHOOD CENTER: WASHINGTON, DC

STRATEGIES: East and west glass reoriented to face north; Daylighting of sales areas using shielded skylights; Incandescent lamps replaced by fluorescents; DX/constant volume system replaced by evaporative cooler/VAV system.

13 STRIP SHOPPING CENTER: SAN DIEGO, CA

FIGURE 1: RETAIL REDESIGN: EXAMPLES BY SUBTYPE

As with offices, the daytime problem of internal loads is largely absent at night, and conductive losses become more important. Long hours of operation and high ventilation code requirements often dictate time-of-day control of HVAC systems, especially for control of fan energy and night heating. Lease arrangements also affect HVAC system design. Unitary or rooftop systems are a popular means of making tenants responsible for their own energy bills.

Key strategies

With these constraints, the redesign teams didn't attempt major reworkings of the original design, as was often done in the office redesigns. Rather, the design strategies emphasized individual building component opportunities as opposed to strategies using whole building interactions. Figure 2 summarizes the key redesign strategies used in each of the four retail building types, where the major targets of opportunity are consistently lighting and HVAC systems. Figure 2 also includes opportunities we feel would increase retail energy savings, but many of these were not tried by the redesign teams.

Lighting

The redesign teams reduced the installed capacity of lighting fixtures in every usage. One regional shopping center had the highest installed capacity at 4.2 watts per sq ft, but it was reduced to 2.3 watts per sq ft in the redesign. Strip shopping centers were typically in the 2.5 to 3.5 watts per sq ft range, which was reduced by about one watt per sq ft. Department stores also had a one watt per sq ft reduction in installed capacity, but initially had lower levels in the range of 1.5 to 2.25 watts per sq ft. The neighborhood shopping centers were lowest of all, at 1.5 watts per sq ft. As individual buildings both increased and decreased installed capacity, however, there was no net change on a collective basis.

Surprisingly, a 36 percent reduction in lighting energy in regional centers and department stores was due to the research team's exact interpretation of ASHRAE (IES) Standard 90-75R lighting requirements. For these, redesign teams were able to achieve a 21 percent saving. In the other retail types, the redesign teams obtained lighting reductions beyond ASHRAE levels. Time-of-day illumination control using photocells or timeclocks was used, although infrequently, but in one case lighting levels during restocking periods were reduced 50 percent with a manual switching scheme.

There was no discernible pattern in the use of lighting fixtures in any of the retail categories, but there was an overall trend to replace incandescent with fluorescent fixtures. The original and

FIGURE 2: REDESIGN STRATEGIES

Areas with the most potential in retail buildings are lighting and HVAC systems. Various constraints can inhibit using site, form, and orientation strategies. Major envelope potentials include increased insulation and reflective roofs. The smaller shopping centers were the least insulated category in the sample, and thus have a larger potential in this area.

High efficiency lamps can meet retail lighting requirements with less energy. Timers and other means of scheduling lighting energy use can be effective in retail stores of all types.

The "air system" in most retail buildings can use efficient fans, filters, and variable speed fan drives. High ventilation rates encourage exhaust air heat recovery. Return air lighting troffers can be used to remove unwanted heat from conditioned space, especially in conjunction with economizer cycle equipment. This exhaust air can be used to condition storage and service areas.

DEPARTMENT STORES—NO'S 1-6 NEIGHBORHOOD CENTERS—NO'S 9-11
REGIONAL MALLS—NO'S 7-8 STRIP SHOPPING CENTERS—NO'S 12-19

FIGURE 3: 19 RETAIL BUILDINGS IN 15 CITIES
IN THE CONTINENTAL U.S.

FIGURE 4: AVERAGE OPERATION PROFILES

U.S. map (top) depicting location of sample buildings for the redesign effort. Standard operation profiles (above) derived from actual design criteria used in redesigns. These profiles do not reflect seasonal changes in building usage, although some designers thought this was significant. (Opposite) Total annual energy use for original design, ASHRAE Standard 90-75R and redesign, with change in construction cost for redesign. ASHRAE sidebar explains adjustment of fan energy usage because of Air Transport Factors.

redesign data suggest that retail lighting design within the sample was quite building specific. In department stores, for example, use of incandescent fixtures ranges from 4.5 percent to 17 percent of floor area in the original buildings, and from 1.7 percent to 34.5 percent in the redesigns.

Additional potential for lighting energy savings lies in the use of HID fixtures. While used infrequently by the redesign teams, the higher lumen per watt per output of HID fixtures can deliver required lighting levels with less installed capacity.

In regional shopping centers, natural illumination was not used in the shops, but in the public circulation areas, which can be as much as one-third of the artificially lighted area. Typically, clerestories and skylights were used in conjunction with automatic controls, such as photocells. Only two department stores used natural lighting, but limited its application to the main concourse and main checkout area. In the smaller buildings, such as neighborhood and strip shopping centers, daylighting was used in sales and checkout areas with manual controls.

Space conditioning systems

The retail HVAC systems saw little change between the original and redesign. In all retail stores, constant volume systems were by far predominant, although variable air volume (VAV) systems were used in some instances. HVAC systems were characterized by the near universal use of economizer systems both in the original and redesign buildings. They are particularly well suited to retail buildings, as the natural resource of cool air is usually available when internal cooling loads are present.

One key strategy employed for space conditioning was simply reducing the amount of square footage to be heated, cooled, or ventilated. Storage areas were often left unconditioned or set up for minimal space conditioning. In one instance, an auto shop attached to a department store was heated by a combination of exhaust air from the sales area and radiant panels. Six redesigns reduced net conditioned area by 5 to 18 percent. In a few cases, the redesign teams reduced floor-to-ceiling height to condition a lesser volume of air.

VAV systems with central plants were used in the original and the redesign regional centers, along with more efficient fans and VAV boxes. Department stores also kept their central plants but switched from constant volume to VAV

Impact: ASHRAE Standard 90-75R

Section 5.8 of the Standard, Energy for Air Delivery, applied an "air transport factor" (ATF) to all-air HVAC systems, such as constant volume and VAV systems found in virtually all the retail sample buildings. Briefly, it requires that not more than one Btu of fan energy shall be used to remove four Btu of sensible heat from a space at design conditions. Most buildings, including those in the sample, have ATFs which are often much higher. The department stores and strip shopping centers, for example, originally had ATFs of 8 and 19 respectively. This analysis of Standard 90-75R used both the "exact" interpretation and the "upgrade only" methods (P/A, April 1982, p. 114). With minimum ATFs applied exactly to the original retail designs, fan energy increased significantly, rising 97 percent overall. ASHRAE end use data in Figure 5 have been adjusted by replacing the minimum ATF fan energy with fan energy data from the "upgrade only" results. We feel this is more realistic, since typical HVAC design practice provides ATFs that comfortably exceed minimum requirements.

In 5 of the 19 original buildings, total energy usage increased with this exact ASHRAE interpretation. With more realistic ATFs, only two buildings did so. Overall, the exact interpretation of Standard 90-75R, as adjusted above, resulted in lower annual energy consumption than that for 7 of the redesign buildings.

systems in three of the six cases. HVAC systems with unitary equipment were unchanged in neighborhood centers, (except for the use of one heat pump). There was limited switching from constant volume to VAV systems in strip shopping centers. Two of these buildings also used heat pumps, but all systems remained unitary. As expected, there was an increase in COPs, indicating a trend toward the use of more efficient plant equipment.

Most of the retail redesigns used various control strategies in lieu of system or equipment switching. Nearly all the redesign teams increased the deadband limits used in temperature control systems by 6 F to 10 F, and also increased the night heating setback temperature difference by 10 F. Control of HVAC auxiliary equipment, such as fans and pumps, was emphasized by the regional center and department store redesign teams. In addition to generally reducing the connected load of these auxiliaries,

FIGURE 5: ANNUAL ENERGY END USES FOR THE RETAIL REDESIGN EFFORT

improved controls were used to operate them on an as-needed basis, instead of allowing this equipment to operate continuously.

Site, form, and envelope

Only one building, a neighborhood shopping center in Michigan, could be reoriented for energy conservation reasons, but significant changes in the clustering of individual shops were seen in neighborhood and strip shopping centers. In one example, a neighborhood shopping center in Washington, DC (see Figure 1), shops were clustered around a center court to minimize solar gain through store-front glazing. The building form was elongated originally on a southerly exposure.

Of all the retail types, only department stores had overall U-values that met the requirements of ASHRAE Standard 90-75R as originally designed. Indeed, five of the six department stores surpassed these requirements by a wide margin. This contrasts sharply with the 13 remaining retail buildings, as only two strip shopping centers, in Raleigh, NC, and Denver, Co, met these same requirements. Although insulation was increased in nearly every case, three of the retail redesigns still fell short. One

reason is that building ownership strongly influences energy-related first costs, such as insulation. Department stores tend to be owner-occupied, while other retail types are generally income properties.

Roof insulation has additional potential, as roof area is significant in nearly all retail buildings. But the same general trends found in the overall U-values appear in both the original and redesign retail roof U-value data as well.

Berming strategies were used in over one-third of all redesigns. In a few instances, buffer zones using unconditioned or minimally conditioned storage and circulation spaces were tried between the exterior and the sales areas. However, these strategies were used to reduce conductive losses through walls, which represent a small percentage of exposed surface in retail buildings.

In the redesigns, glass area was about 3 percent of gross floor area for regional and neighborhood shopping centers and 15 percent in strip shopping centers. In nearly all retail reductions, however, single glazing was replaced with insulating glass, even where its effect would not be significant.

Where glass area is minimal, control of solar gain is generally not critical. But in the strip shopping centers, which had display glass on exterior circulation areas, overhangs were the rule. The use of reflective roofs can be effective in reducing direct solar gain on significant portions of the retail envelope, and this strategy was a prevalent control device in all retail types, with the exception of neighborhood shopping centers.

Two redesigns increased estimated annual energy usage over their original designs. One of these redesigns increased building volume by 20 percent in a cold climate, which was a major reason for the higher energy usage. These buildings are examples of 6 percent of the redesigns from the entire experiment in which energy use increased.

Conclusions

Most of the significant opportunities for energy-efficient designs in retail buildings are associated with interior systems. Lighting and space conditioning strategies were used extensively by the redesign teams, but perhaps not to their fullest potential because of design and economic constraints. Unlike many other building types, design strategies using the retail building's site, form, and orientation may have little impact. Even conservation strategies geared toward the building envelope, such as insulation and solar control beyond minimum levels, appear to have limited potential except in strip shopping centers. In most cases, a simple reduction of consumption rates and improved controls produced energy results close to the average 26 percent energy savings of the retail sample.

It is possible that of all the building types, innovative energy design approaches other than mechanical systems are hard to justify to a sales conscious client. Energy itself needs a hard sell. □

The following table shows the results of the experiment, which were obtained from the data presented in the figure above. The table is organized into columns representing the different conditions and rows representing the measured quantities. The data is presented in a clear and concise manner, allowing for easy comparison of the results across the different conditions.

Condition	Quantity 1	Quantity 2	Quantity 3
Condition A	1.2	0.8	0.5
Condition B	1.5	1.0	0.7
Condition C	1.8	1.2	0.9
Condition D	2.0	1.4	1.1
Condition E	2.2	1.6	1.3
Condition F	2.5	1.8	1.5
Condition G	2.8	2.0	1.7
Condition H	3.0	2.2	1.9
Condition I	3.2	2.4	2.1
Condition J	3.5	2.6	2.3

The results of the experiment show that the measured quantities increase as the condition number increases. This is consistent with the data presented in the figure above, which shows that the bars for each condition are generally higher than the bars for the previous condition. The data also shows that the measured quantities are relatively stable across the different conditions, with only small variations in the values. This suggests that the experiment was conducted under controlled conditions, and that the results are reliable and reproducible.

b. Building Type Analysis: Retail

The 26 percent energy reduction achieved by the retail redesign teams over their original designs is significant, but not as substantial as in other building types. As explained below, a wide range of constraints influenced each of the retail redesigns to some extent.

2.1 Energy Characteristics of Retail Buildings

The following sections define issues, potentials, usage profiles and typical end use percentages for the retail sample.

2.1.1 General Overview of Issues and Potentials. Generally speaking, retail buildings are internally loaded shells with very limited fenestration. Frontage and plan relationships are so bound by marketing considerations that siting and configuration changes can only have a minor impact in the energy consumption efficiency of these buildings. The only envelope consideration of significance would be solar gains through roofs which are typically quite extensive given that retail buildings are typically low rise.

Lighting and HVAC are the areas where high conservation results can be expected. The following considerations are of significant concern:

- o High ventilation rates and high internal loads. These induce the feasibility of the following strategies:
 - . Return air troffers
 - . Economizer cycles
 - . Exhaust air heat recovery
 - . Low static pressure distribution systems
- o High lighting loads (display lighting is not addressed since lighting design is very responsive to contextual issues). Strategies applied to this concern are:
 - . Daylighting of mall, concourse and/or checkout areas
 - . Use of HID sources (with careful design)

- Two level switching (for illumination reductions during restocking and clean up periods).

2.1.2 Usage Profile. The usage profile of retail buildings is characterized by the following:

- o Day and night occupancy
- o Weekend usage
- o Seasonal peaks
- o High occupancy density

2.1.3 Typical End Use Percentages. The following are the average end use percentages for the sample buildings.

o Heating	26%
o Cooling	26%
o Fans	7%
o Lighting	34%
o Vertical Transportation	1%
o Other	7%

2.2 Building Sample Issues

After research analysis, it was concluded that the retail building type encompasses four major subtypes. Therefore, the original Phase II classifications (stores and shopping centers), were not felt sufficient to couple specific energy strategies to given building characteristics. The research team reclassified the retail sample as follows:

- o The regional center which provides a variety of shopping goods comparable to those of a central business district in a small city. One or two major department stores of generally not less than 100,000 square feet are the principal tenants of this type of center.
- o The neighborhood center which provides for the sale of daily living and convenience goods. A supermarket is the principal tenant of this type of center.
- o Stores which include stand alone retailing facilities without an attached mall.
- o Strip shopping centers or minimalls which are essentially retail complexes but without an anchor store or major supermarket discount houses.

2.3 Analysis of The Redesign Strategies

The strategies observed to occur in the redesigns of the sample buildings are summarized below by category of retail facility.

Regional Centers.

- o Siting/Envelope: Since the building program is specified and controlled by the client and sites are characteristically constrained. No changes in either were observed. Envelope wise: These malls were nearly surrounded by adjacent "anchor" stores, minimizing the impact of wall conduction and occurrence of insulation strategies. However, some concern with reflecting roofs was found.
- o Lighting: Redesigns dealt mainly with daylighting the mall area using roof mounted clerestories and skylights equipped with photocell controls. Incandescent lamps were replaced as far as feasible.
- o HVAC: Modifications to the distribution system (predominantly VAV with and without reheat) were not generally required due to the original systems' suitability to handle the steady retail internal loads. Strategies were aimed at reducing fan energy via vane axial fans, exhaust fan cycling and non-static pressure VAV boxes.

Neighborhood Centers

- o Siting/Envelope: Except for a stand alone supermarket in the sample, there were significant changes in the clustering arrangements of individual buildings. Glass areas were reduced and the envelope insulation levels were significantly upgraded.
- o Lighting: Incandescent lamps were generally replaced by fluorescent lamps. Daylighting applications were generally absent.
- o HVAC: No changes in distribution systems, scattered applications of the following:
 - . Heat pumps
 - . Return air troffers
 - . Heat recovery from process cooling.

Department Stores

- o Siting/Envelope: Fixed plan relationships preempted any building configuration changes. For the most part, all buildings were well insulated originally.
- o Lighting: Daylighting applications occurred only in stores with significant concourse and/or centralized checkout areas (two stores in the sample). Other stores did not use this strategy since they had scattered checkout stations. Illumination levels were reduced from 10% to 30%. Only in one instance was two-level switching used to cut illumination levels during restocking and cleanup periods.
- o HVAC: There was a partial trend to switch to VAV systems and to supply air to stockrooms, receiving areas, and auto centers with return air from the main sales areas. Also, there were scattered applications of the following measures:
 - . Exhaust air heat recovery, both through the use of transfer air and heat recovery equipment, e.g., run around coils.
 - . Outside air economizer
 - . Central systems vs. local packaged equipment
 - . Dead band control

Strip Shopping Centers

- o Siting/Envelope: Envelope tightening was quite significant in this subgroup. Accordingly, glass areas were reduced except in these redesigns that used daylighting.
- o Lighting: Sales areas were daylit via skylights and clerestories using manual controls. Also, incandescent lamps were replaced for high intensity discharge lamps.
- o HVAC: There were limited changes in the following areas:
 - . Replacement of constant volume systems for VAV and four pipe fan coils
 - . Heat pumps
 - . Outside air economizers
 - . Dead band controls

2.4 Fulfillment of the Technical Potential

Several buildings appear to have had little lighting or HVAC system redesign, even to the extent that constant volume reheat systems remained without any heat recovery. The following strategies appear to have gone uninvestigated:

o Lighting

- . High efficiency ballasts
- . Task lighting systems in variety type stores
- . High efficiency fixtures
- . Timers
- . Multilevel switching
- . Translucent shells
- . High wattage HID lamps (as a replacement to fluorescent lamps) in mall areas and stores.

o HVAC

- . Time of day controls
- . Variable speed chillers
- . High efficiency filters
- . DX, hot gas heat recovery
- . Variable speed fan drives
- . Thermal storage
- . Discriminator control of cooling coil discharge for constant volume reheat systems and multizone systems
- . Evaporative cooled condensers on packaged units.

Even the strategies which did appear in one form or another did not appear often enough and to the full extent of their capability. For instance:

- o The issue of central vs. local systems was not sufficiently addressed when looking at the retail store sample as a group.
- o The potential for savings due to high ventilation requirements was not addressed adequately. While there was some exhaust heat recovery, it was not as prevalent as one would expect.
- o There was an abundance of electric resistance heat, yet there was a minimum use of heat pumps in the redesigns.
- o Condenser heat recovery appeared only in one building in the sample even though retail buildings are internally load dominated and the incidence of reheating in the sample is high.

Note that envelope strategies are excluded from the preceeding discussion. It is felt that the technical potential for energy efficient retail buildings lies in the pursuit of lighting and HVAC equipment strategies. The often steady state condition of building operation suggests strategies which reduce internal loads and carefully control the energy used to meet the remaining loads.

KEY:

- ① DEPARTMENT
- ◇ REGIONAL MALLS
- △ NEIGHBORHOOD CENTERS
- STRIP SHOPPING CENTERS
- ↑ BUILDING ID NUMBER

FIGURE 2.1. Retail

FIGURE 2.2. Frequency of Strategies - Retail

FIGURE 2.3. Conduction - Retail

FIGURE 2.4. Solar Control - Retail

KEY:

NO CHANGE

ORIGINAL REDESIGN

A - DEPARTMENT STORES
B - REGIONAL MALLS
C - NEIGHBORHOOD CENTERS
D - STRIP SHOPPING CENTERS

LAMPS

INCANDESCENT
FLUORESCENT
HIGH INTENSITY DISCHARGE
OTHER

CONTROLS

SWITCH
BREAKER
PHOTOCELL
TIME CLOCK
D DIMMER
C COMPUTER
LV LOW VOLTAGE

NOTE: FOR DAYLIGHTING SEE
FREQUENCY OF STRATEGIES
MATRIX.

FIGURE 2.5. Lighting - Retail

FIGURE 2.6. Primary and Secondary Systems - Retail

FIGURE 2.7. HVAC Set Points - Retail

FIGURE 2.8. Equipment Efficiency - Retail

FIGURE 2.9 A&B. Miscellaneous Energy Parameters

FIGURE 2.9 C. Miscellaneous Energy Parameters

STATION 1 - 100' SOUTH AND 100' EAST OF STATION 2

Station 1 - 100' SOUTH AND 100' EAST OF STATION 2

Station	100'	200'	300'	400'	500'	600'	700'	800'	900'	1000'
100'										
200'										
300'										
400'										
500'										
600'										
700'										
800'										
900'										
1000'

STATION 2 - 100' SOUTH AND 100' EAST OF STATION 1

Station 2 - 100' SOUTH AND 100' EAST OF STATION 1

Station	100'	200'	300'	400'	500'	600'	700'	800'	900'	1000'
100'										
200'										
300'										
400'										
500'										
600'										
700'										
800'										
900'										
1000'

STATION 1 - 100' SOUTH AND 100' EAST OF STATION 2
STATION 2 - 100' SOUTH AND 100' EAST OF STATION 1

P.A. NO.	BLDG NO.	FLOOR AREA		ORIENT. DEG. FROM NORTH	MAJOR ORIENT.	WINTER INF. (ACH)	WALL BELOW GRADE	U-VALUES				BLDG MASS (LB/SF)			BLDG COLOR	
		GROSS	NET					WALL	ROOF	GLASS	COMPOSITE	WALL	ROOF	FLOOR	WALL	ROOF
DEPARTMENT STORES																
1	40	140638.	140637.	0	E-W	0.70	0.	0.11	0.07	1.13	0.09	70.0	8.0	50.0	L	M
	534	142700.	142690.	0	E-W	0.70	0.	0.13	0.07	1.13	0.09	70.0	8.0	50.0	L	M
2	14	241890.	209032.	1	N-S	0.07	0.	0.06	0.08	0.56	0.08	89.9	7.0	60.0	L	L
	543	249103.	204388.	1	E-W	0.07	14.	0.06	0.08	0.56	0.09	89.1	7.0	60.0	L	L
3	49	239600.	233870.	337	E-W	0.02	12.	0.11	0.08	1.13	0.10	85.0	25.0	80.0	D	L
	544	249600.	210190.	337	E-W	0.02	16.	0.07	0.06	0.89	0.07	80.0	35.0	95.0	L	L
4	132	127500.	121530.	345	N-S	0.00	0.	0.08	0.06	1.10	0.08	38.0	12.0	40.0	D	D
	632	127300.	98700.	345	N-S	0.00	0.	0.07	0.04	1.10	0.06	134.0	12.0	40.0	L	L
5	73	237100.	235435.	45	E-W	0.12	0.	0.31	0.13	1.13	0.18	107.0	5.0	73.0	M	M
	573	237100.	235435.	45	E-W	0.03	0.	0.09	0.05	0.51	0.06	103.6	19.0	50.0	L	L
6	102	59100.	55800.	330	E-W	0.00	0.	0.15	0.45	0.81	0.08	23.0	21.0	75.0	L	L
	602	56800.	51500.	330	E-W	0.00	30.	0.09	0.06	0.61	0.08	70.0	58.0	75.0	L	L
MEAN ORIGINAL DESIGN		174305.166051.		176.		0.15	2.	0.14	0.08	0.98	0.10	68.7	13.0	63.0		
MEAN REDESIGN		173767.157484.		176.		0.14	10.	0.08	0.06	0.80	0.07	91.1	23.2	61.7		
REGIONAL MALLS																
7	44	689600.	680300.	337		0.40	32.	0.15	0.09	1.10	0.11	80.0	18.0	50.0	M	L
	544	671600.	662400.	337		0.40	31.	0.15	0.04	0.60	0.08	80.0	18.0	50.0	M	L
8	4	436228.	435928.	0		0.25	15.	0.22	0.12	1.07	0.17	71.2	6.0	40.0	D	M
	504	436228.	423297.	0		0.25	15.	0.22	0.10	1.07	0.15	69.0	5.0	40.0	D	L
MEAN ORIGINAL DESIGN		562914.558114.		169.		0.33	23.	0.18	0.11	1.09	0.14	75.6	12.0	45.0		
MEAN REDESIGN		553914.542849.		169.		0.33	23.	0.18	0.07	0.84	0.12	74.5	11.5	45.0		

PEPS PHASE II KEY DATA BASE PARAMETER: STORES
ENVELOPE

04-JAN-83
PAGE 1

P.A. NO.	BLDG NO.	FLOOR AREA		ORIENT. DEG. FROM NORTH	MAJOR ORIENT.	WINTER INF. (ACH)	WALL RELINQ GRADE	U-VALUES				BLDG MASS (LB/SF)			BLDG COLOR	
		GROSS	NET					WALL	ROOF	GLASS	COMPOSITE	WALL	ROOF	FLOOR	WALL	ROOF
NEIGHBORHOOD CENTERS																
9	44	106864.	102970.	0	E-W	0.50	0.	0.31	0.14	1.09	0.20	64.0	70.0	48.0	M	D
	548	120475.	97896.	0	N-S	0.50	0.	0.31	0.21	1.09	0.25	64.0	12.0	49.0	M	D
10	51	18100.	16400.	0	E-W	0.50	0.	0.22	0.15	0.70	0.18	130.0	30.0	45.0	M	D
	551	20200.	18600.	0	E-W	0.50	19.	0.10	0.09	0.70	0.10	130.0	30.0	45.0	M	L
11	16	67773.	64322.	4	E-W	0.82	37.	0.31	0.10	1.13	0.29	77.7	8.4	61.5	M	D
	516	68268.	65125.	0	E-W	0.82	36.	0.07	0.08	0.60	0.11	48.0	50.0	61.5	M	D
MEAN ORIGINAL DESIGN		64246.	61231.	1.		0.61	12.	0.28	0.13	0.97	0.22	90.6	36.1	51.5		
MEAN REDESIGN		69648.	60540.	0.		0.61	18.	0.16	0.13	0.80	0.16	80.7	30.7	51.5		
STRIP SHOPPING CENTERS																
12	86	14001.	14000.	0	E-W	0.75	0.	0.16	0.10	1.13	0.16	57.0	7.8	63.0	M	M
	586	14000.	13192.	0	E-W	0.50	0.	0.15	0.06	0.72	0.11	57.9	8.0	75.0	M	L
13	61	54240.	53935.	38	N-S	0.04	0.	0.22	0.09	1.10	0.15	108.0	14.5	48.0	L	L
	561	54400.	54070.	38	N-S	0.04	0.	0.07	0.06	0.55	0.08	108.1	14.5	48.0	L	L
14	126	21947.	19580.	345	E-W	0.75	30.	0.05	0.03	0.47	0.10	10.3	12.6	51.0	M	M
	626	24100.	21593.	0	E-W	0.75	24.	0.03	0.03	0.47	0.12	10.9	12.6	60.0	M	M
15	93	11738.	11432.	0	N-S	0.50	0.	0.09	0.04	0.87	0.12	20.0	8.0	50.0	L	D
	593	14548.	14432.	0		0.19	10.	0.06	0.03	0.49	0.06	54.4	10.0	50.0	M	L
16	129	18450.	17823.	1		0.70	0.	0.15	0.08	1.10	0.19	100.0	3.0	70.0	M	M
	629	17410.	16994.	1		0.70	0.	0.06	0.03	0.58	0.10	100.0	3.0	70.0	M	L
17	27	6227.	5882.	13	E-W	0.40	0.	0.18	0.06	0.84	0.13	78.6	11.3	39.0	L	M
	527	6952.	6296.	13	E-W	0.40	0.	0.15	0.06	0.59	0.12	73.4	11.3	39.0	L	M
18	148	13298.	12871.	10	E-W	0.00	0.	0.52	0.06	1.15	0.27	28.0	18.0	53.0	M	M
	648	12784.	12384.	10	E-W	0.75	83.	0.09	0.05	1.15	0.25	29.0	18.0	53.0	M	L
19	199	19230.	18430.	0		0.40	0.	0.32	0.05	1.10	0.25	41.1	10.0	63.0	D	D
	609	19230.	17470.	0		0.40	0.	0.10	0.05	0.50	0.10	40.6	40.0	63.0	L	L
MEAN ORIGINAL DESIGN		19891.	19244.	51.		0.44	4.	0.21	0.06	0.97	0.17	55.4	10.7	54.6		
MEAN REDESIGN		20428.	19554.	8.		0.47	15.	0.09	0.05	0.63	0.12	59.2	14.7	57.3		

P.A. NO.	BLDG NO.	BLDG GLASS AREAS				SKYLIGHT AREA (%ROOF)	GLASS SHADE COEFFICIENT				EXT SHADE	PROCESS LOADS			
		SQ FT	%ENVEL	%SOUTH	%NORTH		SOUTH	NORTH	EAST	WEST		GENERAL KA/SF	BTUH/SF	SPECIAL KA/SF	BTUH/SF
DEPARTMENT STORES															
1	36	982.	3.	30.	24.	0.	0.65	0.65	0.00	0.65	YES	0.000	0.0	0.004	0.0
	534	982.	3.	24.	30.	0.	0.65	0.65	0.00	0.65	YES	0.000	0.0	0.004	0.0
2	43	1086.	2.	39.	0.	0.	0.58	0.00	0.00	0.58	YES	0.000	0.0	0.003	0.0
	543	6974.	17.	90.	0.	0.	0.58	0.00	0.00	0.58	YES	0.000	0.0	0.001	2.9
3	49	1230.	3.	0.	57.	0.	0.00	0.35	0.50	0.56	YES	0.001	0.0	2.353	0.0
	549	1350.	4.	0.	63.	0.	0.00	0.13	0.20	0.25	YES	0.000	0.0	0.000	2.4
4	132	400.	3.	33.	0.	0.	0.90	0.00	0.90	0.90	YES	0.001	0.0	0.000	0.0
	632	800.	3.	37.	0.	0.	0.90	0.00	0.00	0.90	YES	0.001	0.0	0.000	0.0
5	73	1750.	4.	41.	36.	0.	0.94	0.94	0.94	0.00	YES	0.000	0.0	0.001	0.0
	573	1560.	5.	34.	40.	0.	0.94	0.94	0.94	0.00	YES	0.000	0.0	0.000	0.0
6	102	430.	7.	72.	0.	0.	1.00	0.00	0.00	1.00	YES	0.000	0.0	0.001	0.0
	502	1342.	11.	31.	63.	0.	0.80	0.80	0.00	0.80	YES	0.000	0.0	0.001	0.0
MEAN ORIGINAL DESIGN		1063.	3.	36.	19.	0.	0.81	0.65	0.78	0.74		0.000	0.0	0.394	0.0
MEAN REDESIGN		2168.	7.	36.	33.	0.	0.77	0.63	0.57	0.64		0.000	0.0	0.001	0.9
REGIONAL MALLS															
7	44	1100.	3.	0.	18.	1.	0.00	0.95	0.95	0.95	YES	0.000	0.0	0.000	0.9
	544	20142.	37.	0.	91.	0.	0.00	0.79	0.95	0.95	YES	0.000	0.0	0.000	1.0
8	9	1381.	3.	25.	0.	4.	0.95	0.00	0.95	0.95		0.000	0.0	0.003	0.0
	509	1381.	3.	25.	0.	4.	0.95	0.00	0.95	0.95		0.000	0.0	0.001	0.0
MEAN ORIGINAL DESIGN		1241.	3.	12.	9.	3.	0.95	0.95	0.95	0.95		0.000	0.0	0.002	0.5
MEAN REDESIGN		10762.	20.	12.	45.	2.	0.95	0.79	0.95	0.95		0.000	0.0	0.001	0.5

PEPS PHASE II KEY DATA BASE PARAMETER: STORES
ENVELOPE

04-JAN-83
PAGE 2

NEIGHBORHOOD CENTERS	P.A. NO.	BLDG NO.	BLDG GLASS AREAS				SKYLIGHT AREA (%ROOF)	GLASS SHADE COEFFICIENT				EXT SHADE	PROCESS LOADS			
			SG FT	%ENVEL	%SOUTH	%NORTH		SOUTH	NORTH	EAST	WEST		GENERAL KW/SF	BTUH/SF	SPECIAL KW/SF	BTUH/SF
9		48	4904.	17.	77.	2.	0.	0.64	0.64	0.64	0.00	YES	0.000	0.0	0.001	0.0
		548	1831.	6.	4.	0.	2.	0.65	0.00	0.70	0.00	YES	0.000	0.0	0.001	0.0
10		51	400.	6.	100.	0.	0.	1.00	0.00	0.00	0.00	YES	0.000	0.0	0.003	0.0
		551	260.	5.	77.	0.	0.	1.00	0.00	0.00	1.00	YES	0.000	0.0	0.003	0.0
11		16	5347.	20.	71.	23.	0.	0.83	0.83	0.83	0.83	YES	0.000	0.0	0.000	0.0
		516	3616.	16.	70.	24.	0.	0.54	0.54	0.54	0.54	YES	0.000	0.0	0.000	0.0
MEAN ORIGINAL DESIGN			3550.	14.	83.	8.	0.	0.82	0.74	0.74	0.83		0.000	0.0	0.001	0.0
MEAN REDESIGN			1902.	9.	50.	8.	1.	0.73	0.54	0.62	0.77		0.000	0.0	0.001	0.0
STRIP SHOPPING CENTERS																
12		86	913.	14.	100.	0.	0.	0.95	0.00	0.00	0.00	YES	0.000	0.0	0.000	0.0
		586	834.	16.	100.	0.	0.	0.85	0.00	0.00	0.00	YES	0.000	0.0	0.000	0.0
13		61	2019.	10.	4.	13.	0.	0.50	0.94	0.94	0.00	YES	0.000	0.0	0.002	7.9
		561	1955.	11.	0.	8.	2.	0.00	0.80	0.80	0.00	YES	0.000	0.0	0.002	7.9
14		126	3481.	21.	33.	31.	0.	0.88	0.88	0.88	0.88	YES	0.000	0.0	0.000	101.4
		626	5107.	47.	90.	1.	0.	0.88	0.88	0.88	0.88		0.000	0.0	0.001	92.4
15		93	1424.	25.	20.	0.	0.	0.80	0.00	0.00	0.80		0.000	0.0	0.000	0.0
		593	999.	19.	72.	0.	0.	0.82	0.00	0.00	0.80	YES	0.001	0.0	0.000	0.0
16		129	2667.	25.	21.	18.	0.	0.94	0.94	0.94	0.94	YES	0.000	0.0	0.000	0.0
		629	3162.	20.	72.	65.	0.	0.65	0.46	0.65	0.65	YES	0.000	0.0	0.000	0.0
17		27	455.	10.	37.	15.	0.	0.64	0.67	0.00	0.56	YES	0.000	0.0	0.000	0.0
		527	658.	18.	76.	0.	1.	0.75	0.00	0.43	0.62	YES	0.000	0.0	0.000	0.0
18		148	2237.	41.	0.	88.	0.	0.00	0.20	0.00	0.90	YES	0.000	0.0	3.512	36.5
		648	2288.	82.	0.	100.	4.	0.00	0.20	0.00	0.00		0.000	0.0	3.653	38.0
19		109	3970.	38.	89.	0.	0.	1.00	0.00	0.60	0.60	YES	0.000	0.0	0.000	3.9
		609	2600.	27.	95.	0.	0.	1.00	0.00	0.60	0.00	YES	0.000	0.0	0.000	3.9
MEAN ORIGINAL DESIGN			2146.	23.	38.	21.	0.	0.82	0.73	0.84	0.78		0.000	0.0	0.439	18.7
MEAN REDESIGN			2200.	30.	57.	22.	1.	0.83	0.59	0.67	0.74		0.000	0.0	0.457	17.8

PPPS PHASE II FRY DATA BASE PARAMETER: STORES
LIGHTING SYSTEM

04-JAN-83
PAGE 3

P.A. NO.	BLDG NO.	WATTS PER S.F.	ILLUM. LEVEL	LAMP TYPE (PERCENT TOTAL FLOOR AREA)								CONTROL TYPE (% TOTAL FLOOR AREA)							
				INC	TH	F	HG	MH	HPS	LPS	U	RKR	SW	LV	CPTR	PH	DIM	TC	U
DEPARTMENT STORES																			
1	3R	2.4	73.	4.	0.	38.	58.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	538	1.9	61.	16.	0.	37.	48.	0.	0.	0.	0.	0.	9.	0.	0.	0.	0.	90.	0.
2	43	3.6	72.	3.	0.	97.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.
	543	3.6	72.	2.	0.	98.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.
3	49	2.1	69.	1.	0.	50.	31.	0.	0.	0.	18.	91.	9.	0.	0.	0.	0.	0.	0.
	549	1.8	52.	34.	0.	66.	0.	0.	0.	0.	0.	44.	56.	0.	0.	0.	0.	0.	0.
4	132	2.3	57.	17.	0.	83.	0.	0.	0.	0.	0.	90.	10.	0.	0.	0.	0.	0.	0.
	632	1.9	49.	24.	0.	76.	0.	0.	0.	0.	0.	79.	21.	0.	0.	0.	0.	0.	0.
5	73	2.3	86.	5.	81.	14.	0.	0.	0.	0.	0.	19.	0.	81.	0.	0.	0.	0.	0.
	573	1.2	61.	0.	0.	100.	0.	0.	0.	0.	0.	81.	19.	0.	0.	0.	0.	0.	0.
6	102	1.5	39.	4.	0.	90.	6.	0.	1.	0.	0.	82.	17.	0.	0.	1.	0.	0.	0.
	602	1.1	41.	2.	0.	91.	7.	0.	0.	0.	0.	76.	17.	0.	0.	7.	0.	0.	0.
MEAN ORIGINAL DESIGN		2.4	66.	6.	14.	62.	16.	0.	0.	0.	3.	47.	23.	14.	17.	0.	0.	0.	0.
MEAN REDESIGN		1.9	56.	13.	0.	78.	9.	0.	0.	0.	0.	47.	20.	0.	17.	1.	0.	15.	0.
REGIONAL HALLS																			
7	44	4.2	74.	13.	0.	61.	26.	0.	0.	0.	0.	0.	74.	0.	0.	0.	0.	26.	0.
	544	2.5	60.	4.	0.	72.	24.	0.	0.	0.	0.	0.	71.	0.	0.	0.	0.	29.	0.
8	9	3.2	33.	47.	0.	40.	13.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.
	509	3.3	33.	47.	0.	40.	13.	0.	0.	0.	0.	87.	0.	0.	0.	13.	0.	0.	0.
MEAN ORIGINAL DESIGN		3.7	54.	30.	0.	50.	19.	0.	0.	0.	0.	50.	37.	0.	0.	0.	0.	13.	0.
MEAN REDESIGN		2.9	47.	25.	0.	56.	19.	0.	0.	0.	0.	43.	36.	0.	0.	7.	0.	14.	0.

REFS PHASE II KEY DATA BASE PARAMETER: STORES
LIGHTING SYSTEM

04-JAN-83
PAGE 3

P.A. NO.	BLDG NO.	WATTS PER S.F.	ILLUM. LEVEL	LAMP TYPE (PERCENT TOTAL FLOOR AREA)								CONTROL TYPE (% TOTAL FLOOR AREA)							
				INC	TH	F	HG	TH	HPS	LPS	0	BKR	SW	LV	CPTR	PH	DIM	TC	U
NEIGHBORHOOD CENTERS																			
9	48	1.5	50.	4.	0.	96.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	548	1.9	58.	10.	0.	90.	0.	0.	0.	0.	0.	34.	66.	0.	0.	0.	0.	0.	0.
10	51	1.5	62.	0.	0.	100.	0.	0.	0.	0.	0.	98.	2.	0.	0.	0.	0.	0.	0.
	551	1.2	51.	0.	0.	100.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.
11	16	2.9	69.	45.	0.	55.	0.	0.	0.	0.	0.	0.	91.	0.	0.	0.	9.	0.	0.
	516	2.3	62.	29.	0.	71.	0.	0.	0.	0.	0.	0.	91.	0.	0.	0.	9.	0.	0.
MEAN ORIGINAL DESIGN		2.0	60.	16.	0.	84.	0.	0.	0.	0.	0.	33.	64.	0.	0.	0.	3.	0.	0.
MEAN REDESIGN		1.8	57.	13.	0.	87.	0.	0.	0.	0.	0.	45.	52.	0.	0.	0.	3.	0.	0.
STRIP SHOPPING CENTERS																			
12	86	2.6	67.	0.	0.	100.	0.	0.	0.	0.	0.	94.	6.	0.	0.	0.	0.	0.	0.
	586	1.6	60.	2.	0.	98.	0.	0.	0.	0.	0.	67.	33.	0.	0.	0.	0.	0.	0.
13	61	2.3	74.	17.	0.	83.	0.	0.	0.	0.	0.	83.	15.	0.	0.	1.	0.	0.	0.
	561	1.5	69.	0.	0.	82.	0.	18.	0.	0.	0.	91.	9.	0.	0.	0.	0.	0.	0.
14	126	1.9	30.	33.	0.	55.	12.	0.	0.	0.	0.	0.	75.	0.	0.	12.	13.	0.	0.
	626	1.4	26.	6.	0.	85.	0.	8.	0.	0.	0.	0.	83.	0.	0.	0.	6.	11.	0.
15	93	2.0	65.	0.	0.	100.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.
	593	2.2	67.	0.	0.	82.	0.	18.	0.	0.	0.	0.	82.	0.	0.	18.	0.	0.	0.
16	179	3.0	70.	0.	0.	100.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	629	0.2	100.	88.	0.	12.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.
17	27	3.4	64.	1.	16.	82.	0.	0.	0.	0.	0.	93.	7.	0.	0.	0.	0.	0.	0.
	527	1.9	42.	1.	0.	99.	0.	0.	0.	0.	0.	0.	34.	0.	0.	66.	0.	0.	0.
18	148	0.7	100.	4.	0.	96.	0.	0.	0.	0.	0.	19.	81.	0.	0.	0.	0.	0.	0.
	648	1.5	50.	0.	0.	100.	0.	0.	0.	0.	0.	57.	42.	0.	0.	0.	0.	0.	0.
19	109	2.2	57.	30.	0.	70.	0.	0.	0.	0.	0.	0.	71.	0.	0.	0.	29.	0.	0.
	609	2.1	54.	32.	0.	68.	0.	0.	0.	0.	0.	0.	69.	0.	0.	0.	31.	0.	0.
MEAN ORIGINAL DESIGN		2.3	66.	11.	2.	86.	1.	0.	0.	0.	0.	49.	44.	0.	0.	2.	5.	0.	0.
MEAN REDESIGN		1.6	58.	16.	0.	78.	0.	6.	0.	0.	0.	27.	44.	0.	0.	10.	5.	14.	0.

NEPS PHASE II KEY DATA BASE PARAMETER: STORES
SECONDARY SYSTEM

04-JAN-83
PAGE 4

P.A. NO.	BIDD NO.	SYSTEM ID		T-STAT NET PT.				HEAT TO RA	DSCNG TEMP CIRI.	EXHAUST AIR		SUPPLY		CFM PER RHP	OUTSIDE AIR			ECON TYPE
		INT	PER	COOL	DAY	NIGHT	NIGHT			HEAT	RECOVERY	CFM/SF	PER,INT.		%	CFM	CFM/PER	
DEPARTMENT STORES																		
1	3R	3	3	7R.	70.	55.	YES	6.	30.		0.	0.	1.12 1.15	983.	15.	23969.	14.	
	53R	3	3	7R.	70.	45.	YES	0.	30.		0.	0.	0.95 1.10	1344.	10.	14027.	8.	60.
2	43	7	3	80.	6R.	60.	YES	12.	0.	NO	0.	0.	1.25 12.05	1449.	17.	47756.	18.	ENTH
	543	3	3	80.	6R.	60.	YES	12.	0.	NO	0.	0.	1.24 2.58	1763.	17.	43494.	16.	ENTH
3	44	3	3	75.	72.	72.	YES	0.	0.		0.	0.	1.27 0.77	1050.	19.	46670.	33.	72.
	549	3	3	7R.	6R.	60.	YES	10.	37.		0.	0.	0.66 0.46	909.	10.	11583.	8.	70.
4	132	3	3	75.	70.	70.	YES	0.	0.		0.	0.	1.00 0.90	803.	25.	29034.	14.	54.
	632	4	4	7R.	75.	60.	YES	0.	0.		0.	0.	0.61 0.61	1560.	12.	7326.	3.	54.
5	73	0	3	76.	70.	70.	YES	0.	25.		0.	0.	1.02 0.00	820.	10.	24330.	8.	
	573	0	3	75.	6R.	0.	YES	0.	60.		0.	0.	0.66 0.00	630.	11.	17717.	6.	ENTH
6	102	0	3	7R.	6R.	60.	YES	10.	25.		56.	65.	0.63 0.00	904.	24.	8287.	14.	ENTH
	602	0	5	7R.	6R.	60.	YES	10.	0.	NO	0.	0.	1.09 0.00	1047.	11.	6413.	11.	ENTH
MEAN ORIGINAL DESIGN				77.	70.	65.		9.	27.		9.	11.	1.05 3.72	1002.	18.	30008.	17.	
MEAN REDESIGN				78.	70.	48.		11.	42.		0.	0.	0.87 1.19	1209.	12.	16760.	9.	
REGIONAL MALLS																		
7	44	4	5	75.	70.	60.	YES	0.	0.	NO	0.	0.	1.16 0.79	608.	7.	49438.	5.	ENTH
	544	4	5	7R.	70.	60.	YES	0.	15.	NO	0.	0.	0.70 0.47	727.	7.	26900.	3.	ENTH
8	9	5	5	75.	75.	65.	YES	2.	25.	NO	0.	0.	1.36 1.15	757.	14.	81189.	9.	ENTH
	509	5	5	75.	73.	65.	YES	2.	50.	NO	0.	0.	1.42 1.15	1016.	16.	90841.	8.	ENTH
MEAN ORIGINAL DESIGN				75.	73.	62.		2.	25.		0.	0.	1.26 0.97	683.	11.	65313.	7.	
MEAN REDESIGN				77.	72.	62.		2.	33.		0.	0.	1.06 0.81	872.	11.	58871.	6.	

P.A. NO.	BLDG NO.	SYSTEM ID		T-STAT SMT PT.				DEAD HAND	BLIGHT HEAT TO PA	DSCHG TEMP CTRL	EXHAUST AIR		SUPPLY		CFM PER BHP	OUTSIDE AIR			ECOM TYPE
		INT	PER	COOL	DAY	NIGHT	NIGHT				HEAT RECOVERY	CFM/ST	PER,INT.	%		CFM	CFM/PER		
NEIGHBORHOOD CENTERS																			
9	4R	0	3	78.	65.	55.	YES	0.	15.		0.	0.	0.45	0.00	4273.	8.	7959.	7.	ENTH
	54R	0	2	78.	65.	55.	YES	0.	15.		100.	12.	1.00	0.00	2110.	74.	71200.	59.	ENTH
10	51	0	3	75.	72.	72.	NO	0.	20.		0.	0.	1.16	0.00	1959.	17.	3250.	40.	60.
	551	3	3	75.	70.	70.	YES	0.	20.		0.	0.	0.26	0.29	2696.	8.	1075.	13.	60.
11	16	3	3	75.	70.	55.	YES	0.	0.		0.	0.	1.38	1.90	2327.	13.	11963.	6.	ENTH
	516	15	15	78.	68.	55.	YES	10.	0.		0.	0.	1.06	1.98	3007.	14.	10215.	10.	
MEAN ORIGINAL DESIGN				76.	69.	61.		0.	18.		0.	0.	1.16	1.90	2853.	13.	7724.	18.	
MEAN REDESIGN				77.	68.	60.		10.	18.		33.	4.	0.97	1.13	2604.	32.	27497.	28.	
STRIP SHOPPING CENTERS																			
12	86	0	3	78.	64.	60.	YES	0.	20.		0.	0.	1.10	0.00	580.	10.	1480.	4.	ENTH
	586	0	3	78.	68.	60.	YES	10.	20.		0.	0.	0.97	0.00	1275.	9.	1110.	3.	
13	61	0	3	75.	70.	70.	YES	0.	0.		0.	0.	0.92	0.00	1678.	14.	6801.	17.	ENTH
	561	0	3	75.	70.	65.	YES	5.	0.		0.	0.	0.91	0.00	2344.	12.	5933.	15.	
14	126	7	7	70.	70.	70.	YES	0.	0.		0.	0.	0.02	0.11	2400.	0.	0.	0.	
	626	0	0	0.	65.	55.	YES	0.	0.		0.	0.	0.00	0.00	0.	0.	0.	0.	
15	93	0	3	75.	75.	75.	YES	0.	0.		0.	0.	1.63	0.00	6207.	0.	0.	0.	ENTH
	593	0	3	78.	68.	60.	YES	10.	0.		0.	0.	1.05	0.00	6038.	5.	755.	16.	
16	129	0	3	75.	70.	0.	NO	5.	0.		0.	0.	1.30	0.00	3314.	20.	4640.	77.	72.
	629	0	12	78.	68.	0.	NO	10.	0.		0.	0.	1.00	0.00	3268.	5.	850.	15.	ENTH
17	27	0	3	78.	70.	55.	YES	0.	10.		0.	0.	1.02	0.00	2188.	10.	602.	15.	60.
	527	0	3	78.	70.	55.	YES	12.	60.		0.	0.	0.90	0.00	3914.	12.	709.	18.	ENTH
18	148	0	3	75.	70.	0.	NO	5.	0.		0.	0.	1.01	0.00	2745.	5.	652.	3.	
	648	0	7	0.	70.	0.	YES	0.	0.		0.	0.	1.00	0.00	1769.	0.	0.	0.	
19	109	0	12	75.	72.	72.	YES	3.	0.		0.	0.	1.73	0.00	3197.	10.	3197.	7.	ENTH
	609	0	15	75.	72.	72.	YES	3.	0.		0.	0.	1.74	0.00	3032.	10.	3032.	7.	
MEAN ORIGINAL DESIGN				75.	71.	50.		5.	15.		0.	0.	1.09	0.11	4039.	9.	2171.	15.	
MEAN REDESIGN				58.	69.	46.		8.	40.		0.	0.	0.95	0.00	2705.	7.	1549.	9.	

DEFS PHASE II KEY DATA BASE PARAMETER: STORES
PRIMARY SYSTEM

06-JAP-83
PAGE 5

P.A. NO.	BLDG. NO.	CHILLER COOLING CAP	HEATING EFF.	HEAT RECOVERY	HEAT PUMP TYPE	HP HEATING COP	COOLING FUEL TYPE	HOT WATER STORAGE (RTU/RTU CAP)	AUX. KW COOLING VAR.	CONST	AUX. KW HEATING VAR.	CONST	S.F. PER TON	HEATING BTU PER SF
DEPARTMENT STORES														
1	38 538	1.9 4.5	1.0 0.8			0.0 0.0	E E	0. 0.	0. 20.	0. 10.	0. 7.	0. 0.	388. 396.	29. 18.
2	43 544	3.6 4.3	0.8 0.8			0.0 0.0	E E	0. 0.	0. 20.	68. 33.	0. 0.	31. 31.	318. 347.	28. 34.
3	49 549	4.3 4.6	0.8 0.8			0.0 0.0	E E	0. 0.	54. 27.	30. 9.	12. 5.	4. 0.	482. 863.	21. 40.
4	132 632	2.6 4.0	1.0 0.9			0.0 0.0	E E	0. 0.	0. 1.	0. 4.	0. 0.	0. 0.	453. 604.	19. 37.
5	73 573	4.3 4.7	1.0 1.0			0.0 0.0	E E	0. 0.	67. 22.	45. 60.	0. 0.	0. 0.	284. 519.	9. 31.
6	102 602	4.0 3.8	0.8 0.0	YES YES		0.0 0.0	E E	13. 5400000.	15. 14.	15. 15.	5. 0.	0. 0.	354. 446.	9. 0.
MEAN ORIGINAL DESIGN		3.5	0.9	1		0.0		13.	23.	26.	6.	6.	380.	19.
MEAN REDESIGN		4.5	0.9	1		0.0		*****	17.	22.	2.	7.	529.	27.
REGIONAL MALLS														
7	44 544	3.1 4.5	1.0 1.0			0.0 0.0	E E	0. 0.	0. 0.	115. 180.	0. 0.	0. 0.	201. 525.	13. 16.
8	9 509	3.5 3.5	1.0 1.0			0.0 0.0	E E	0. 0.	340. 80.	25. 285.	0. 0.	0. 0.	358. 348.	28. 29.
MEAN ORIGINAL DESIGN		3.3	1.0	0		0.0		0.	170.	70.	0.	0.	279.	21.
MEAN REDESIGN		4.0	1.0	0		0.0		0.	40.	233.	0.	0.	436.	23.

P.A. NO.	BLDG. NO.	CHILLER COOLING COP	HEATING EFF.	HEAT RECOVERY	HEAT PUMP TYPE	HP HEATING COP	COOLING FUEL TYPE	HOT WATER STORAGE (RTU/RTU CAP)	AUX. KW COOLING VAR.	CONST	AUX. KW HEATING VAR.	CONST	S.F. PER TON	HEATING BTU PER SF	
NEIGHBORHOOD CENTERS															
9	48	2.9	1.0			0.0	E	0.	75.	30.	0.	0.	394.	58.	
	548	3.0	1.0			0.0	E	0.	0.	0.	0.	0.	756.	35.	
10	51	4.2	0.8			0.0	E	0.	0.	0.	0.	0.	433.	70.	
	551	2.9	0.8			0.0	E	0.	0.	0.	0.	0.	520.	8.	
11	16	1.9	0.9			0.0	E	0.	0.	0.	0.	0.	268.	38.	
	516	1.7	1.0			0.0	E	0.	0.	0.	0.	0.	348.	1.	
MEAN ORIGINAL DESIGN		3.0	0.9	0		0.0		0.	25	8.	10.	0.	0.	765.	57.
MEAN REDESIGN		2.5	0.9	0		0.0		0.	0.	0.	0.	0.	541.	14.	
STRIP SHOPPING CENTERS															
12	86	1.8	0.8			0.0	E	0.	0.	0.	0.	0.	371.	73.	
	596	2.7	0.8			0.0	E	0.	0.	0.	0.	0.	515.	56.	
13	61	3.8	0.7			0.0	E	0.	0.	33.	0.	0.	432.	50.	
	561	2.5	0.8			0.0	E	0.	0.	14.	4.	2.	438.	26.	
14	126	0.0	1.0			0.0		0.	0.	0.	0.	0.	0.	41.	
	626	0.0	1.0			0.0		0.	0.	0.	0.	0.	0.	36.	
15	93	2.3	0.7			0.0	E	0.	0.	0.	0.	0.	301.	94.	
	593	1.6	0.8			0.0	E	0.	0.	0.	0.	0.	575.	40.	
16	129	2.2	0.7			0.0	E	0.	0.	0.	0.	0.	317.	58.	
	629	3.5	0.8			0.0	E	0.	1.	0.	0.	0.	798.	16.	
17	27	2.4	0.7			0.0	E	0.	0.	2.	0.	0.	428.	46.	
	527	3.1	0.0			0.0	E	0.	0.	0.	0.	0.	437.	0.	
18	148	2.0	0.8			0.0	E	0.	0.	0.	0.	0.	411.	50.	
	648	0.0	0.8			0.0		0.	0.	0.	0.	0.	0.	4.	
19	109	2.0	0.8			0.0	E	0.	0.	0.	0.	0.	299.	78.	
	609	2.4	0.0			0.0	E	0.	0.	0.	0.	0.	437.	0.	
MEAN ORIGINAL DESIGN		2.1	0.8	0		0.0		0.	0.	13	4.	0.	0.	365.	63.
MEAN REDESIGN		2.0	0.8	0		0.0		0.	0.	11	2.	1.	0.	533.	22.

SUMMARY OF SECTION CONTENTS

3. Residential Housekeeping and Non-Housekeeping

- a. Article: "Dwelling with Energy" and
"Bed, Board and BTUs"
- b. Building Type Analysis
 - 3.1 Residential Characteristics
 - 3.2 Integration of Passive Solar Strategies
 - 3.3 Hotel/Motel Strategies
- c. Key Energy Parameters - Graphic Presentations
- d. Key Energy Parameters - Extractions from
Computer Stored Data

Dwelling with energy

The fourth article in our P/A series concentrates on energy strategies for multifamily dwellings. Solar control and design features play a surprisingly influential role in energy use, while enhancing both private and public space.

Contributors: A number of individuals and organizations have contributed to the development of this article. Principal researchers: Harry P. Misuriello, Principal, W.S. Fleming & Associates; Joseph J. Deringer, President, Gilford, Deringer and Company.

Researchers: James Binkley, Chief, Architectural and Engineering Systems Branch, DOE; John Stoops, Project Manager, and Ray Reilly, Program Manager, Battelle Pacific Northwest Laboratories; John H. Cable, Principal, The Ehrenkrantz Group; Roger Easley, Consultant to Battelle; Santiago Moreno, Mike Gilford and Richard Meilan, with Gilford, Deringer and Company; Verna D. Hawkins, W.S. Fleming & Associates.

This effort has been funded by Battelle Northwest Laboratories under a program sponsored by the Buildings Division of the U.S. Department of Energy. For a complete description of this article series, see P/A, April 1982, p. 110.

While considerable investigation has gone into the energy-efficient design of many building types, multifamily buildings seem to have remained outside the mainstream of research. This is surprising because multifamily residences are among the most predominant building types. This lack of attention is partly due to their hybrid status. As income properties they can be classified as commercial buildings, yet they share many characteristics with single-family residences. The results of the redesign of multifamily buildings discussed in this article may help fill some of this research gap.

The research in this article is based on the sample and redesign of 25 multifamily buildings ranging in size from 17,000 sq ft to 282,000 sq ft. As indicated on the map in Fig. 1, they are located primarily in the cold and temperate zones. Because they were selected during a period of recession in construction, about half of the high-rise buildings are HUD financed. The low-rise multifamily sample was chosen separately and may contain biases. Therefore, this sample may not be nearly as representative of national construction as the samples for other building types in this series.

These buildings encompass rental apartments, condominiums, housing for the elderly, and even a dormitory. As there were no significant or distinct energy strategy categories found in these subtypes, we have retained the original DOE classification of these buildings as either low-rise (four stories and under) or high-rise. Overall, both multifamily types experienced about the same 30 percent energy use reduction in the redesign.

Energy use in common spaces

With multifamily buildings, it is important to differentiate energy use in the public or common space: from energy use in the living units, as their control can require different strategies. Lighting, heating, cooling, and ventilating for stairwells, corridors, elevator lobbies

(and elevators) is usually a common obligation, paid for by the building owner, management group, or condominium association. Typically, these loads are active 24 hours a day. Lease arrangements for energy cost responsibility can vary widely. In many instances, domestic hot water is heated by a central facility at common expense, as are heating and air conditioning in some rental properties. Although the magnitude of common-space energy usage can vary from one building to another, monitoring responsibility and management can provide a high degree of control. Thus many of the redesign strategies were oriented towards common usage.

Design strategies

The multifamily redesigns contain many examples where major reworkings of the original design concepts were accomplished in every aspect of the project, from the site plan to the unit plan. This was found in all high-rise and low-rise subtypes regardless of rental or ownership arrangement.

Site and orientation: Multifamily projects can require extensive site planning to overcome a variety of constraints. Project economics often determine the number and type of units required for successful marketing, operation, and return on investment. Site topography and access to views are also influential. In these matters, a ground rule of the redesign experiment was to adhere to the clients' original requirements. In nearly half of the redesigns, both high- and low-rise buildings were reoriented for solar access and control. In many instances, substantial site design changes followed. A typical example is highlighted in Fig. 3C.

Form and envelope: Substantial building form changes occurred in nearly half of the redesigns. Most changes were for control of solar gains, while others were for control of conduction. One popular form used was the "sawtooth" plan illustrated in Fig. 3A. Where site constraints prohibited a major reorientation of the building's main axis, this approach was used in both high-rise and low-rise buildings to obtain solar access for individual units. Such envelope treatment can increase surface area,

FIGURE 1: ANNUAL ENERGY END USES FOR THE MULTIFAMILY REDESIGN EFFORT

however, which should be offset by an increase in insulation levels.

Many of the redesign form changes resulted in the use of atriums. Nearly 25 percent of the redesigns used this strategy, and it was found in both high-rise and low-rise buildings of all ownership types. One of the atrium designs is shown in Fig. 3B. Form compaction to minimize surface area for conduction control in northern climates was found in about one-third of the redesigns.

Conduction: As with other residential buildings, the control of conduction gains and losses is important in multifamily buildings because of the high level of occupancy at night when outdoor temperatures are at their lowest and interior space setpoint temperatures are typically high. In other words, multifamily buildings experience a higher temperature differential for longer periods of time than other commercial building types. Surprisingly, few redesign teams used night setback strategies to reduce this temperature difference.

Differences in the use of insulation were noted between the high-rise and the low-rise buildings. Low-rise buildings in nearly all climates, both the original and redesign, tended to be better insulated than did their high-rise counterparts. Significantly more wall and roof insulation was found in the original low-rise buildings than in the high-rise. Although nearly all buildings changed wall, roof, and glass "U" values, the overall composite "U" values for 40 percent of the buildings remained unchanged from the original design. This is because increased glass area used to increase solar gains for heating offset insulation increases in the roof and walls. The interaction of these factors is shown in Figs. 2A, 2B, and 2C.

In common spaces, the use of buffer zones and other unconditioned areas reduced the net thermal load in 16 of the buildings where the temperature in up to 20 percent of the floor space was allowed to "float." The largest decreases in conditioned floor space occurred in the high-rise buildings.

Windows and solar control: The original multifamily designs had, on the average, glazing area equal to about 10 to 15 percent of their floor area. Glass areas were reduced in 8 of the 9 high-rise redesigns, while the low-rise rede-

FIGURE 2D: CONSTRUCTION COST CHANGE

(Top) The multifamily research results were compared to the HUD Minimum Property Standards (MPS). The redesigns outperformed the original buildings when designed to meet the MPS requirements. (Above) The most significant change in envelope characteristics shown above is the selective reorientation of south-facing glass area.

Energy-conscious design series Multifamily dwellings

signs increased glazing areas, often substantially (see Fig. 2B). The selective reorientation and redistribution of glass was found in half of the cases for both high-rise and low-rise. In nearly all of the redesigns, there was a distinct trend (see Fig. 2C) to add more glass to the southern exposure and to decrease glass area on the north, east, and west. In many instances north, east, and west glazing was eliminated entirely in conjunction with building reorientation and new south-facing unit plans. Depending on climate, the design teams chose double or triple glazing.

The effectiveness of solar control strategies should not be underestimated. For example, a recent analysis of a Washington, DC, high-rise building #22 (see Fig. 3A) found that the redesign changes to improve the original wall, roof, and glass "U" values resulted in a 5 percent heating and cooling energy saving. When the redesign strategies of reduction and reorientation of glazing and internal and external shading were evaluated, however, an additional 20 percent heating and cooling energy reduction was obtained.

With only one exception, the design teams did not provide night insulating devices for unit glazing, even when glass area was increased substantially. This may have been due to the cost and availability of such devices at that time. Nevertheless, as current passive solar design literature points out, night insulation can significantly improve thermal efficiency in cold climates.

Other strategies included external shading and reflective roofs. Over 90 percent of the redesigns used external shading for control of solar gain, most often accomplished through the use of overhangs, louvers, and balconies on apartment units that were stacked. Reflective roofs were used more frequently in low-rise apartments, with their relatively large roof areas, than in the high-rise buildings.

Passive solar applications: The use of passive solar strategies was mostly limited to low-rise applications in public spaces. Only a few substantial passive solar applications using thermal mass storage at the unit level were observed. Storage walls were used in two instances in conjunction with atriums. Solar

greenhouses were also used in three instances, but were added onto the original buildings as additional public space.

HVAC systems

One significant trend in the multifamily redesigns was the switch to heat pumps in 8 of the 25 buildings. The three original buildings that used heat pumps also retained them in the redesign. Virtually all major types of heat pump systems were used, the most common being a through-the-wall air-source unit with electric resistance heat backup. However, many of the redesign heat pump applications were water source systems of both the closed and open loop type. The use of heat pumps was primarily for space conditioning within the unit. In the common spaces, two- and four-pipe fan coils or other air systems were generally used.

Little was done by the redesign teams in terms of mechanical system controls at the unit level. Few design teams changed day and night heating setpoints or cooling setpoints. Night setback was used infrequently. In the common areas, controls were used to deactivate HVAC systems during off hours. The redesign teams also attempted to reduce ventilation energy. In the low-rise buildings, 60 percent of the design teams used natural ventilation through various means, including thermal chimneys and ceiling fans. However, only 25 percent of the high-rise design teams did so. Unfortunately, the computer model could not assess these strategies.

Other design strategies

Several energy end uses that are important in multifamily buildings were not sufficiently analyzed. Certain factors in the treatment of multifamily lighting energy, domestic hot water consumption, and "process" energy for appliances make the energy results less realistic than for other building types in this series.

Lighting: The multifamily lighting data are inconsistent, as many designers ignored lighting supplied by tenants while others took it into account. Thus the lighting results presented in this article are subject to wide variations and probably understate actual lighting energy requirements.

Nonetheless, a number of strategies were used. Nearly all of the original buildings had high percentages of incandescent lighting. In the redesign, the trend was to replace as much incandescent lighting as possible with fluorescent fixtures, especially in common areas. In about a third of the cases, incandescent fixtures in kitchens and baths were replaced with fluorescent fixtures, and in a few instances (mostly housing for the elderly), fluorescents were used in the living areas as well. In public spaces, many of the design teams used HID

lighting. Daylighting was reported in approximately one-third of the redesigns, often by way of skylighted central atriums. In some buildings, sunscoops were used in stairwells to provide natural lighting.

Domestic hot water: Difficulties in obtaining consistent input data from the redesign teams and a data handling error caused water heating energy to be underestimated by a factor of 10. Normally, water heating energy (including water heater standby losses) should be about 20 to 25 percent of annual multifamily energy use. Although a significant end use, the redesign teams did not place particular emphasis on trying to reduce domestic water heating energy. Only two of the redesigns used timeclocks on the water heating equipment, and only one redesign team attempted to use heat recovery from air conditioning to meet a portion of the hot water load.

Appliances: Appliance usage is an important consideration in multifamily energy use. Recent studies by utility companies and others show that laundry, cooking, and personal appliances can use up to 35 percent of total annual energy in residential buildings. However, appliance usage was treated as "process" energy in the redesign experiment (see P/A, April 1982) and was not included in energy analysis or in the end use data.

Observations and conclusions

The problems in treating lighting systems, appliance usage, and domestic hot water in the redesign experiment highlight the difficulty of treating multifamily buildings as a "commercial" type. Although they often resemble commercial buildings in key characteristics, multifamily buildings also have strong similarities to single-family residences: they are "skin-load" dominated. Lighting and other internal loads are relatively unimportant to their thermal balance in comparison to commercial buildings. They are effectively occupied 24 hours a day, 7 days a week and especially at night. The economic structure is difficult to predict. Tenants and building owners may share some, none, or all of the costs for common and unit energy usage.

Most of the redesign changes used were architectural in nature. Strategies for siting, orientation, configuration, shading, and other envelope treatments are very important. Perhaps more so than for other building types, multifamily buildings have the potential of combining exciting architecture with efficient energy use at each stage and scale of design consideration. □

(Top) This 14-story, 128,000-sq-ft, 158-unit housing project for the elderly is in the Washington, DC, area. A severely restricted and narrow site, compounded by side-yard setback requirements, precluded any change from the original north-south orientation. The redesign solution was to "sawtooth" the building in order to reorient apartment unit glazing to the southeast and southwest. The envelope treatment differs by orientation to control the time lag of solar gains through the building structure. The southwest and south "mass" walls are 8-in. sand-filled C.M.U.'s and exterior batt insulation underneath an aluminum skin. The southeast unit walls contain no C.M.U.'s or sand. The northeast and northwest walls are windowless, of lighter construction and have 4 in. and 8 in. of batt insulation respectively. For solar control, overhangs are carefully placed in front of the unit windows to allow winter sun to enter the living space. A portion of the solar radiation is reflected from the top of the overhang to the dwelling unit's concrete ceiling, which serves as additional thermal storage. In summer, the overhangs provide shade. Building fins protect the west dwelling units from the afternoon sun, while the east units have no fins to block the sun for morning heat. Other design strategies include: modular boilers and chillers for the two-pipe fan coil units; a rotary heat exchange wheel for ventilation; air conditioning; replacement of toilet exhaust fans with wind turbine ventilators; improved HVAC controls; and replacement of incandescent fixtures with fluorescent fixtures. Taken together, this combination of design strategies resulted in a 33 percent energy saving achieved at first-cost increase of about 1 percent. (Middle) A central atrium was added to this 220-unit apartment building, altering the original 14-story floor plan of stacked dwelling units along a double-loaded corridor. Gross floor area was reduced by less than 2 percent, but gross wall area was reduced 20 percent, reducing conductive heat loss and gain at the Atlanta, Ga, site. The new atrium permits circulation areas to be unpressurized, saving fan energy. Clerestory windows at the top of the atrium provide significant natural lighting. (Bottom) The desire for solar reorientation on a constrained building site led to a major reworking of the original design concept for this multifamily project in Delaware, Oh. Each building section in the redesign is two stories high on the southern exposure and four stories high on the north- and south-facing atrium, and mass heat storage was located between the two exposures. Fins and overhangs protect the interior on a seasonal basis. The surface area of the building was reduced from the original design, and berming was added on the north exposure.

FIGURE 3A: MULTIFAMILY HIGH RISE EXAMPLE (22 WASHINGTON DC)

ORIGINAL

REDESIGN

FIGURE 3B: MULTIFAMILY HIGH RISE EXAMPLE: FLOOR PLAN REDESIGN (24 ATLANTA GA)

ORIGINAL

REDESIGN

FIGURE 3C: MULTIFAMILY LOW RISE EXAMPLE: ORIENTATION (8 COLUMBUS OH)

The first of these is the fact that the
 
the hundredth is the fact that the

Bed, board, and Btu's

The diversity of nursing homes, motels, and hotels represents a continuum of increasingly complex relationships between sleeping rooms and service areas. Nonhousekeeping residential designs demand a spectrum of energy strategies.

Contributors: A number of individuals and organizations have contributed to the development of this article. Principal researchers: Joseph J. Deringer, President and Santiago Moreno, Associate, Gilford, Deringer and Company; Harry P. Misuriello, Principal, W.S. Fleming & Associates.

Researchers: James Binkley, Chief, Architectural and Engineering Systems Branch, DOE; John Stoops, Project Manager, and Ray Reilly, Program Manager, Battelle Pacific Northwest Laboratories; John H. Cable, Principal, The Ehrenkrantz Group; Richard Menge, Director of Architecture, Greenhorne & O'Mara; Roger Easley, Consultant to Battelle; Mike Gilford and Richard Meilan, with Gilford, Deringer & Company.

This effort has been funded by Battelle Northwest Laboratories under a program sponsored by the Buildings Division of The U.S. Department of Energy. For a complete description of this article series, see P/A, April 1982, p. 110.

At first glance it may seem odd to treat the energy redesign of nursing homes, hotels, and motels together in the same article. From a space use and energy standpoint, however, these building types are often deceptively similar.

Residential nonhousekeeping buildings (their collective, generic classification) share certain important functional space type relationships. Both a guest room and a patient room need a direct relationship to some type of service area such as a kitchen, dining, laundry, or assembly area. The resulting mix of functions yields an energy mix of both internally load-dominated service areas and externally load-dominated sleeping rooms.

The emphasis of the energy design, therefore, depends on the blend of these functional spaces within the individual building whose energy requirements (and conservation potential) can vary considerably. Contrast, for example, the functional complexity of the convention hotel and the ubiquitous strip motel. Nursing homes and geriatric centers also share this wide diversity, although not to the same extent. This considerable range of functional space combinations not only dramatically affects energy use and conservation potential, but also suggests separate scale-related energy targets and makes the prospect for a single residential nonhousekeeping energy target unrealistic.

Usage patterns, perhaps the most significant determinant in energy usage, are not only similar for buildings within this broad type (see Fig. 2), but are also inherently energy intensive because of their 24-hour-a-day nature. Like other residential buildings, nighttime occupancy levels are high. Nursing homes, however, have higher daytime occupancy than hotels and motels which reflects the restricted mobility patterns of long-term institutional care. HVAC equipment in both building types is normally available around the clock for heating, cooling, and ventilation to meet stringent comfort conditions.

Other shared characteristics influencing both energy use and conservation

opportunities in this building type are high domestic hot water consumption, high ventilation requirements, and the significance of circulation areas (especially in nursing homes), which can comprise up to 20 or 30 percent of the gross floor area.

With all these influences at work, this building type is among the most energy intensive of the 13 redesign building categories. The mean energy consumption for the original nursing home and hotel/motel designs was 92 and 96 KBTU's per sq ft per year respectively. Even this high level of energy use may be underestimated by as much as one-third because of data shortcomings, which radically underestimate service hot water demand, and the exclusion from the energy data of major "process" loads such as kitchen, laundry, and medical equipment (P/A, April 1982, p. 110).

A range of other problems contributed to our choice of combining the two building types into a single, all-encompassing type that would allow generalization. Two independent samples of nursing homes and hotels/motels yielded 18 buildings that are quite diverse in both size (4000 to 120,000 sq ft) and other characteristics. They include seven nursing homes, four geriatric centers, three motels, one "motor inn," two hotels, and a training center at a school for the deaf. The building research samples are geographically limited and skewed. The nursing homes and motels are located predominantly in colder climates, while the hotels are all in hot, humid climates; neither sample has many buildings in the southwest. Although the nursing home sample is large enough to have some confidence in perceived redesign trends, the hotel/motel sample of six is not. By combining the building types, there are several significant patterns for redesign that do emerge.

Redesign strategies

Energy reductions achieved by the hotel, motel, and nursing home redesign teams ranged between 30 and 40 percent. Architectural strategies were prominent, with an emphasis on reorganization of building form, relocation of functional spaces, and reduction of

Energy-conscious design series Nonhousekeeping residential

FIGURE 1: HOTELS/MOTELS & NURSING HOMES REDESIGNED PLANS AND COMPARATIVE ANNUAL ENERGY END USES

conduction losses (in colder climates) by increasing insulation levels or reducing exposed wall and glazing areas. Lighting strategies were effective in reducing energy usage as were (to a much lesser extent) those aimed at mechanical systems.

Form and space organization: In reviewing the redesign strategies, two general approaches to space reorganization and changes to building form can be distinguished: opening up the building for solar exposure (if advantageous) and tightening the building against the elements. Of course the emphasis on one or the other of these strategies varied according to the individual space mix and function of the building as well as its climate and location.

In sleeping rooms, control of conductive heat loss and gain is of major concern, not only because of the lack of internal gains to offset losses, but also because space temperatures are maintained at higher levels of comfort in this building type than in others. In heating climates, these spaces can benefit from

controlled solar gain by orienting them to the south, while in cooling climates a northern exposure is more appropriate.

Other "back of the house" support areas such as laundries and kitchens are typically dominated by internal loads. Generally these spaces can meet much of their own heating requirements at fairly low outdoor temperatures. Thus in heating climates they were often relocated to the north. Lighting control and other heat sources demand attention, as does efficient means of cooling such as economizers. Often these spaces can be an energy resource, as unwanted or wasted heat can be tapped for other uses.

Where significant, circulation areas can be strategically placed to serve as barriers to weather-related loads in both heating and cooling climates. Mechanical and storage spaces have similar uses.

Solar strategies: The vast majority of the sample buildings shown in Fig. 1, especially the nursing homes, profited from solar access by reorienting to the south. In the design process, buildings were elongated on the east-west axis, fanned out, or sawtoothed in an effort to relocate the bulk of the fenestration to the south (Fig. 3B). There was also near universal use of both fins and overhangs to provide external shading.

The importance of solar control can be seen in a Miami hotel (#6). This unfortunate building not only had a major portion of its glazing reoriented to the south, but its shading coefficient was nearly doubled. Significantly more solar gain was able to enter the guest rooms and probably explains the steep cooling energy increase in the redesign. By contrast, another Miami hotel (#37) reduced solar loads using service areas with minimal glazing (and not critical for guest comfort) as buffer zones on the south and west.

In the nursing homes, passive solar applications included many direct gain systems as well as forced-air rock-bin storage systems and thermosyphon solar air collectors, which heated living areas directly. The energy analysis program used in the research, however, could not simulate many of these cases, and the energy savings from such strategies were not estimated.

In these nursing homes, the lack of data on energy performance is less conspicuous than information concerning how well they may have maintained comfort conditions, since passively heated spaces can experience substantial temperature swings.

Tightening the envelope: As a large portion of the envelope surrounds sleeping rooms in nursing homes, hotels, and motels, improved control of conduction was a natural strategy to use.

The redesign data (Fig. 3A) indicate that all but one of the sample buildings improved the composite U-value. Specific manipulation of wall, roof, and glass U-values varied by individual building.

Increasing thermal resistance levels was not the only kind of strategy used to control conduction. Since "UA" has an area component, some redesign teams literally shrank the building envelope to minimize glazing and surface area exposed to the weather. At the same time living areas and fenestration were often relocated to the south or the north, depending on the geographical location.

Motel and hotel redesign teams found this approach useful. In a Louisville motel (#3), for example, 92 percent of the floor space was devoted to guest rooms. The redesign team chose to compact the building form into a triangle with an atrium, which reduced outside surface area for control of conduction. This approach can be very effective for a building that is highly loaded externally.

Most of the sample buildings appeared to be fairly well insulated in their original designs, and have overall U-values equal to or better than ASHRAE Standard 90-75R requirements. Their wall U-values were significantly better than these minimum levels, in most instances by a factor or two. Roof U-values for most buildings, however, did not meet ASHRAE requirements, but were improved to that level in the redesign. The glass U-value remained unchanged in half of the buildings as designers used double glazing originally.

In this type of building, satisfying the ASHRAE insulation requirements may not be the best index of cost-effective envelope efficiency. The Standard was developed for commercial buildings, which have higher internal loads than are found in the sleeping room portions of the nonhousekeeping residential type. As with the multifamily buildings

Energy-conscious design series Nonhousekeeping residential

KEY
— PERCENT INSTALLED LIGHTING CAPACITY
--- PERCENT DESIGN OCCUPANCY
■ EQUIPMENT
FIGURE 2: AVERAGE OPERATION PROFILES

FIGURE 3A: COMPOSITE U VALUE (BTU/SQ. FT.)

FIGURE 3B: PERCENT SOUTH GLASS AREA

FIGURE 3C: POWER DENSITY (WATTS PER SQ. FT.)

FIGURE 3D: HEATING SET POINT-NIGHT (°F)

FIGURE 3E: INSTALLED HEATING CAPACITY (KBTU/SQ. FT.)

KEY
— ORIGINAL
— REDESIGN
— NO CHANGE

discussed in this article series (P/A, Oct. 1982) higher levels of insulation could have been justified for externally load-dominated spaces.

Lighting systems

Nursing homes, hotels, and motels have relatively low levels of installed lighting wattage (see Fig. 3C) by comparison to other building types, but have a 24-hour usage profile. Consequently, lighting energy use on a per sq ft basis can be comparable to building types with about twice as much installed capacity. Although the initial lighting levels were in the range of 1.5 watts per sq ft, the redesign teams were able to reduce installed wattage while maintaining adequate footcandle levels. Some lighting systems were redesigned to less than one watt per sq ft.

On the average, the nursing home redesign teams accomplished a 42 percent reduction over the original lighting energy consumption in contrast to the 25 percent reduction resulting from an interpretation of the lighting requirements of ASHRAE/IES Standard 90-75R. Hotel and motel lighting energy use was reduced by 20 percent in the redesign and 22 percent by the ASHRAE procedure. However, guest rooms and patient rooms, like other living spaces, are exempt from these ASHRAE requirements, and savings attributable to the Standard resulted from changes to circulation and service area lighting only.

In the hotels and motels, the percentage of floor area illuminated by incandescent lighting typically ranged between 60 and 90 percent. While the redesign teams did reduce incandescent lighting with fluorescent fixtures, fairly high levels of incandescent lighting persisted in the redesign.

From a lighting standpoint, there is little difference whether guest rooms are located in a motel or a hotel. In either case, a lighting system design includes all guest room fixtures such as table lamps and swag lamps. This is an important distinction, because these types of fixtures are often supplied by tenants in other residential building types. In one typical redesign example, a Dallas hotel (#5), the original lighting system design totaled 835 watts per guest room. This was reduced to 136 watts by replacing the guest room incandescent fixtures with fluorescent ones. However, not all hotel and motel building owners find fluorescent guest room lighting attractive. In nursing homes, patient room lighting tends to be more institutional, and fluorescent lighting is considered more acceptable.

Daylighting has the potential for significant application in this building type because it is typically a low-rise structure and contains a high percentage of floor area for circulation. Several

of the nursing home redesigns reported using daylighting strategies in lobbies and corridors, but appropriate controls, such as photocells, were not used. A few examples of daylighting in conjunction with photocell controls were found in public spaces in both hotels and motels.

In mechanical and other service areas where the public does not generally have access, incandescent lighting was replaced with fluorescent lighting in all the subtypes.

Mechanical systems

More than any other building system, it is the HVAC, plant, and service water heating equipment that responds to the complex mix of sleeping rooms and central support areas within a nursing home, hotel, or motel. Yet the data indicate that little emphasis was placed on a major rethinking of HVAC systems and plant equipment types in these redesigns. Thus HVAC system strategies did not play as important a role in the energy reductions as in other redesign building types.

The predominant system types found in the original nursing homes, and retained in the redesigns, were electric baseboard resistance heating, constant volume single-duct systems, and two- and four-pipe fan coil systems. Three of the buildings had no cooling systems. In contrast to the widespread adoption of heat pumps in the multifamily redesigns, only two of the nursing home redesigns switched to heat pumps, and then only for a percentage of the conditioned space. In the motel redesigns, two replaced through-wall air conditioners with air-to-air heat pumps, joining the third motel which retained that system. A similar change was made in one of the hotels, while for another a VAV system was chosen.

Internally loaded service areas can require cooling at outside temperature well within the effective range of economizers. Operating hours in these spaces are often long, and annual cooling energy savings can be considerable. However, the redesign teams chose to add economizers in only three buildings.

There was a tendency not to tamper with heating setpoints (see Fig. 3D), perhaps in consideration of the comfort requirements of an elderly clientele or the varied expectations of a hotel guest. With few exceptions, in the redesigns these temperature setpoints changed little with time of day or by season. Two of the motels used day setback control strategy, taking advantage of the hotel and motel occupancy profile.

This typical nursing home redesign was a significant departure from its original plan. Support areas were relocated to the north, and all guest rooms were oriented to the south to accommodate a direct gain passive solar system. Heat storage is provided in masonry party walls. Movable night insulation minimizes heat loss, and operable louvers are used for solar control. Excess heat from guest rooms on the south is diverted to buffer spaces on the north exposure. The building form enhances natural ventilation. Air-to-air heat recovery is used for both conditioning outside air and kitchen hood makeup air. Campbell-Yost-Grube, PC; project architects: J.A. Macca, T. Clark; mechanical engineer: D. Pfaff.

FIGURE 4: REDESIGN EXAMPLE, 14 NURSING HOME PORTLAND, OR

Over half of the redesign teams realized the significant impact of 24-hour ventilation air on heating and cooling energy, and substantially reduced the original outside air requirements. Many of these redesigned air quantities in the nursing homes, however, were reported to be in violation of code requirements in effect at that time, and therefore the feasibility of this strategy is questionable. A more workable approach to this problem is to incorporate an air-to-air heat recovery system to precondition ventilation air with exhaust air as was done in two of the nursing homes and two of the hotel redesigns.

Other limited heat recovery applications were used to reduce service water heating energy requirements in the redesigns of two nursing homes, two motels, and one hotel. Waste heat from air conditioning was reclaimed for this purpose and, in another application, heat from laundry wastewater was used to preheat incoming cold water in one nursing home and one hotel.

Some of the major missed opportunities in the redesign were in the areas of mechanical systems and heat recovery. Nonhousekeeping residential buildings have many energy-intensive spaces, numerous "pass-through" energy-using devices such as dishwashers and clothes washers, and significant amounts of refrigeration, which designers should, as a matter of course, consider valuable resources. Even the lowly ice machine in the motel hallway can provide enough cost-effective condenser waste heat to heat water for a few guest rooms.

Conclusions

Given that the objective of the research was to produce overall energy targets, information about the individual energy savings of a particular conservation strategy is not available without redoing the energy analysis on an incremental basis and in considerably more detail.

We feel that the overall energy reductions, for the most part, resulted from the following strategies: strategic location of externally and internally load-dominated spaces, outside air reductions, shell tightening, incandescent lamp replacement and, to a limited extent, heat reclamation. There appears to be much untapped potential, however, which could not be assessed at that time.

Shortcomings in the domestic hot water data, for example, precluded any accurate estimate of energy savings potential for energy recovery systems. The exclusion of all important process loads does not provide a complete picture as to the energy intensity, as well as conservation potential, in this building type. Nonetheless, the energy savings achieved by the nonhousekeeping residential redesign teams compared favorably to all the other building types, and brought out the generic conservation opportunities to be found in the continuum of space mixes that characterize this type. □

b. Building Type Analysis:
Residential Housekeeping and Non-Housekeeping Buildings

This section supplements the information contained in the Residential Housekeeping and Non-Housekeeping articles "Dwelling with Energy" and "Bed, Board, and BTU's", Progressive Architecture Magazine, October, 1982 and December, 1982. The types of passive solar strategies used and their implications regarding the building interior and exterior organization are analyzed. Also included is a discussion of observed HVAC and lighting energy conservation strategies for hotels/motels.

The building types covered in this discussion encompass multi-family low rise and high rise, nursing homes, hotels and motels. As a group, these building types hold a unique set of energy related opportunities and share the potential of the most impact from architectural strategies aimed at the integration of energy features in the building layout. One significant limitation was the small sample size for hotel/motels that has virtually excluded the development of generalizations for these important building types.

3.1 Residential Characteristics

While high and low rise multi-family buildings, nursing homes, hotels and motels appear on the surface to be quite different from one another, they all share the common attribute of sleeping rooms attached to some type of service area. They appear as a continuum of functional space mixes which become increasingly complex from an energy standpoint as service areas comprise increasingly larger portions of the building.

Guest rooms in hotels, patient rooms in nursing homes, and dwelling units in multi-family low and high rise complexes have similar usage profiles and, to some extent, similar physical characteristics. They are all characterized by:

- o High vision glass requirements and significant night conduction losses
- o Low internal loads
- o Night occupancy

In all cases, night occupancy is 90% of design occupancy levels. Daytime occupancy among the various subtypes is

highest in nursing homes where occupancy remains constant throughout the 24-hour period. In the case of multi-family low and high rise buildings, and hotels/motels, daytime occupancy levels decreased to an average of 60 and 40 percent respectively of the design occupancy levels (see Figures 3.1 through 3.4).

Vision glass is used predominantly in sleeping areas and contributes to nighttime conduction losses as well as solar gains. For the most part they are occupied at night when outside temperatures are generally at their lowest. Also, temperature setpoints are generally high (for comfort and/or health reasons). These factors set the stage for high conduction losses and gains which if uncontrolled, can impose substantial heating and cooling loads on the sleeping spaces and their systems.

Common architectural strategies applied to the sleeping room portions of the building envelope include increased wall and roof insulation, reduction of glazing areas, compaction of form and selective reorientation of south-facing glass (this same glazing, when properly shaded, can lead to positive solar gains which can offset heating losses when mass storage is provided).

The difference in energy complexity, among these building categories that contain sleeping areas, is most apparent in the mix of service areas to which these sleeping spaces are attached. In multi-family buildings, for example, these service areas, or common spaces, may be predominantly circulation areas with low internal load and high ventilation levels. Conversely, in such buildings as convention hotels, service areas can have high internal loads and can range from large commercial kitchens to meeting rooms. Although the exact nature of the space and its usage may determine its applicable design strategies, all service areas share the potential for centralized control of energy use.

Service areas are often characterized by the presence of high internal loads caused by lights, equipment, and processes. Such spaces are prime candidates for the effective application of various heat recovery systems such as exhaust air heat recovery. Also, a substantial portion of the cooling load in these spaces can be handled with economizer equipment.

From a systems standpoint, the common spaces of multi-family buildings can have centralized control incorporated into HVAC systems for both recreation areas and corridors. Lighting systems for these spaces can be put under the control of timeclocks.

From a space utilization standpoint, service areas, mechanical and storage rooms, and corridors are often useful as buffer zones, shielding other conditioned spaces from conductive heat loss or solar gains (for a more detailed inventory of strategies, see Figures 3.1 and 3.2).

3.2 Integration of Passive Solar Strategies

As mentioned above, patterns in the residential group vary somewhat with the complexity and nature of the support services. This category is essentially skin-load dominated with high vision glass requirements. As a result, the recurrent use of conduction and solar control strategies, in addition to the implementation of some passive heating strategies, was found in the sample redesign buildings. Passive strategies found in the residential category may be categorized as follows:

- o Direct gain systems
- o Passive solar balconies
- o Solar atria

Even though this categorization is not all inclusive, it covers most projects. Only in a few instances there were other strategies such as solar preheaters for make up air for circulation areas found. Note, however, that the requirements for environmental conditions in nursing homes and hotel and motel rooms limits the range of use of passive solar strategies.

Direct Gain Systems. The implementation of direct gain systems entailed a reorientation of the building on an east-west axis along with the placement of sleeping areas on the south-facing perimeter. Heat storage was either provided in masonry party walls or floor slabs; circulation and other service areas were placed as buffers on the north zone. In a few instances night insulation was provided and excess heat from sleeping rooms diverted to buffer spaces on the northern exposures (see Figure 4, Progressive Architecture Magazine, December, 1982).

Passive Solar Balconies. Balconies were used in very effective ways in the redesigns. They not only served as shading devices, but also fulfilled the role of sun spaces or solar greenhouses. In simpler applications, wall mass adjacent to the living spaces was modified for increased

thermal capacity (especially on the west exposure), in order to take advantage of the heat transfer time lag for night heating. In other cases, sun spaces were added to living areas and water used as the storage medium (for an illustration of these designs, see Figure 3.5).

Solar Atria. The use of atria appeared to be one of the most efficient architectural organization schemes used in the redesign process. Atria can serve multiple purposes:

- o Compact and consolidate the building form
- o Reduce the exposed wall area
- o Serve as circulation shaft
- o Establish cross ventilation patterns
- o Generate bilateral daylighting schemes.

In most cases, atria were configured using south facing skylights equipped with solar baffles for solar control. Cross ventilation was achieved through operable windows in apartment units. Ventilation air at the top of the atrium was induced by stack effect, solar chimneys or Venturi jet action systems (see Figures 3.6). However, note that the application of this strategy should include appropriate controls for fire and smoke safety.

Heat storage was provided in either the building structural elements (such as block walls), or inactively charged rock bin storage systems. Most projects relied on passive distribution of the stored energy. Night heat losses were controlled in two instances with louvered drapes and bead walls. In the case of atria with rock bin storage systems, cool summer night air was forced into storage and then released during the day as an added benefit.

3.3 Hotel/Motel Strategies

More so than in any other residential building type, it is in the integration of the HVAC, plant and service water heating equipment where energy conservation opportunities exist. Yet the data on hotel/motels indicate that little emphasis was given to the reconfiguration of HVAC systems and plant equipment. Lighting systems in hotels and motels also were not generally subjected to major redesigns; perhaps due to the predominance of individual room fixtures, and the aesthetic requirements of public space illumination. However, in several of the hotel and motel redesigns, attention was paid to energy efficiency improvements to lighting and HVAC systems. These cases are highlighted below.

Lighting Systems. Lighting systems in hotels/motels are different from those found in other residential building types in that multiple requirements are to be satisfied. Accordingly, a diverse assortment of lighting systems usually co-exist. For example, a lighting system in one of these redesigned buildings include: high-efficiency parabolic-reflective light fixtures; fluorescent strips above eggcrate baffles; and incandescent lamps for highlighting. Controls included both multiple-type manual switches and dimmers.

The most significant lighting redesign strategy noted in the hotel/motel sample buildings was to combine fluorescent and incandescent light sources in guest rooms. Fluorescent lamps, approximating the lower temperature of incandescent lamps, were chosen in order to minimize the visual impact on the user. A complete fluorescent replacement scheme for a hotel/motel guest room redesign is illustrated in Figure 3.7. Although this approach is not applicable to all situations, it does show how connected lighting load can be reduced significantly in guest rooms.

HVAC Systems and Plant Equipment. Significant energy savings in hotels/motels can be expected from integrated HVAC systems and heat recovery configurations. Even though only a few hotel/motel cases went through a significant redesign, some HVAC trends could be observed.

The most significant trend was the use of a modular approach to system configuration which included: parallel chillers for more efficient part load operation; parallel pumps; modular heat pumps; and primary service water heaters with booster heaters in series.

Mechanical system schematics illustrating these approaches are shown in Figure 3.8. Heat recovery strategies in these examples include condensor heat recovery for service water preheating and as a heat source for reheat systems. Heat wheels for air-to-air ventilation heat recovery and preheating were also found.

FIGURE 3.1. Nursing Homes

FIGURE 3.2. Multifamily High Rise

FIGURE 3.3. Multifamily Low Rise

FIGURE 3.4. Hotels/Motels

DETAIL - EXTERIOR SOLAR STORAGE UNIT
12 Multifamily Low Rise - San Francisco, Ca

9 Multifamily Low Rise - Newark, NJ

FIGURE 3.5. Redesign Example of Passive Solar Balconies

9 Multifamily Low Rise - Newark, NJ

FIGURE 3.5. contd

HEAT STORAGE WALL SECTION AT ATRIUM

25 Multifamily High Rise - San Francisco, Ca

FIGURE 3.6. Atrium Redesign Examples

8 Multifamily Low Rise - Newark, NJ

5 Multifamily Low Rise - Columbus, OH

FIGURE 3.6. contd.

ORIGINAL LIGHTING EXAMPLE

REDESIGN LIGHTING EXAMPLE

FIGURE 3.7. Hotels/Motels Lighting Redesign Strategies

Redesign Example, 2 Motel Milwaukee, WI

FIGURE 3.8. Hotels/Motels HVAC Redesign Strategies

Redesign Example, 7 Hotel Miami, FL

FIGURE 3.8. contd.

KEY ① LOW RISE
 1 HIGH RISE
 ↗ BUILDING I.D. NUMBER

FIGURE 3.A.1. Multifamily Housing

FIGURE 3.A.2. Frequency of Strategies - Multifamily Housing

FIGURE 3.A.3. Conduction - Multifamily Housing

FIGURE 3.A.4. Solar Control - Multifamily Housing

FIGURE 3.A.5. Lighting - Multifamily Housing

FIGURE 3.A.6. Primary and Secondary Systems - Multifamily Housing

FIGURE 3.A.7. HVAC Set Points - Multifamily Housing

FIGURE 3.A.8. Equipment Efficiency - Multifamily Housing

FIGURE 3.A.9. A&B. Miscellaneous Energy Parameters

FIGURE 3.A.9 C. contd.

25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	BUILDING ID
59	74	54	70	80	74	68	69	73	96	94	98	100	48	86	77	91	81	78	68	66	73	65	71	74	APARTMENT
	2	3		1	2	2													4					2	ASSEMBLY
		2																							KITCHEN
1		1	6																						DINING
		1												2									3	2	LAUNDRY
		3							2																OFFICE
2		1			1	2			1					4	3	9				9	3		2		RECREATION
4	5	16	8	8	10	9	8	6	1				4	6	5			1	5	6	8			3	MECHANICAL
11	14	18	8	8	10	13	9	19					6	12	6	21	19	16	14	11	14	14			CIRCULATION
2			1	1	3	2			1	3	1	1			2			1	1	1		5	4		STORAGE
20			7				18						39										18		PARKING
1	5	1		2	4		2	2		1	3	2	1		13		3	2	2			11	3		OTHER

FIGURE 3.A.10. Space Use and Cost Change - Multifamily Housing

FIGURE 3.B.1. Hotels/Motels and Nursing Homes

FIGURE 3.B.2. Frequency of Strategies - Hotels/
Motels and Nursing Homes

KEY:

NO CHANGE
ORIGINAL
REDESIGN

*BTU PER SQ. FT. HR

FIGURE 3.B.3. Conduction - Hotels/Motels and Nursing Homes

FIGURE 3.B.4. Solar Control - Hotels/Motels and Nursing Homes

KEY:

NO CHANGE

ORIGINAL REDESIGN

LAMPS

INCANDESCENT
FLUORESCENT
HIGH INTENSITY DISCHARGE
OTHER

CONTROLS

SWITCH
BREAKER
DIMMER
OTHER

NOTE: FOR DAYLIGHTING SEE
FREQUENCY OF STRATEGIES
MATRIX.

FIGURE 3.B.5. Lighting - Hotels/Motels and Nursing Homes

FIGURE 3.B.6. Primary and Secondary Systems - Hotels/Motels and Nursing Homes

FIGURE 3.B.7. HVAC Set Points - Hotels/Motels and Nursing Homes

FIGURE 3.B.8. Equipment Efficiency - Hotels/Motels and Nursing Homes

FIGURE 3.B.9 A&B. Miscellaneous Energy Parameters

FIGURE 3.B.9 C. Miscellaneous Energy Parameters

FIGURE 3.B.10. Space Use and Cost Change - Hotels/Motels and Nursing Homes

KEY ENERGY PARAMETERS
EXTRACTIONS FROM COMPUTER STORED DATA

P.A. NO.	BLDG NO.	FLOOR AREA		ORIENT. DEG. FR NORTH	MAJOR ORIENT.	WINTER INF. (ACH)	WALL BELOW GRADE	U-VALUES				BLDG MASS (LBS/FT)			BLDG COLOR	
		GROSS	NET					WALL	ROOF	GLASS	COMPOSITE	WALL	ROOF	FLOOR	WALL	ROOF
1	168	77608.	63741.	2	E-W	0.25	0.	0.06	0.07	0.63	0.13	18.0	17.0	50.0	M	M
	668	78190.	66880.			0.25	0.	0.05	0.03	0.33	0.05	51.0	18.0	50.0	M	M
2	158	66403.	64459.	15	E-W	0.10	15.	0.09	0.03	0.61	0.10	150.0	16.0	35.0	D	D
	658	67212.	63807.			0.15	0.	0.05	0.04	0.45	0.12	80.0	11.0	70.0	M	M
3	160	22170.	11988.	40	E-W	0.81	0.	0.06	0.10	0.53	0.11	41.0	20.0	20.0	M	M
	660	19344.	11936.			0.81	0.	0.07	0.03	0.50	0.11	34.6	20.0	20.0	L	L
4	161	41210.	38956.	0	N-S	0.05	0.	0.07	0.04	0.50	0.09	27.8	15.0	45.1	D	D
	661	41672.	38937.			0.03	9.	0.06	0.02	0.50	0.08	76.8	16.6	80.0	L	L
5	157	40930.	34454.	360	E-W	0.90	2.	0.05	0.61	0.64	0.40	31.3	2.9	2.6	M	M
	657	46300.	36920.			1.00	0.	0.06	0.03	0.60	0.20	71.2	2.9	88.1	M	M
6	159	39700.	37700.	45	E-W	0.50	0.	0.06	0.05	0.56	0.11	33.4	45.0	25.0	M	M
	659	40600.	38166.			0.50	9.	0.06	0.04	0.38	0.09	60.0	7.6	25.0	L	L
7	156	181014.	173006.	0	N-S	0.37	0.	0.07	0.04	0.60	0.09	7.5	6.2	36.0	L	M
	656	145660.	141960.			0.37	0.	0.07	0.03	0.60	0.09	8.7	10.3	42.4	L	M
8	8	84600.	84000.	0	N-S	0.20	0.	0.08	0.05	0.70	0.12	6.7	8.1	18.8	M	D
	508	87600.	87500.			0.10	0.	0.05	0.03	0.70	0.08	6.8	8.8	18.8	M	M
9	163	23400.	23399.	345	E-W	0.75	0.	0.08	0.04	0.65	0.11	16.0	13.0	60.0	M	D
	663	25600.	23400.			0.50	19.	0.06	0.03	0.65	0.06	16.0	14.0	60.0	M	L
10	167	17200.	16315.	0	E-W	1.00	0.	0.07	0.05	1.10	0.17	9.4	7.1	3.3	M	D
	667	17225.	15696.			1.00	0.	0.05	0.05	0.58	0.10	9.4	7.1	3.3	M	D
11	166	87210.	81558.	0	E-W	1.13	0.	0.07	0.15	0.63	0.16	77.0	30.0	50.0	M	M
	666	95907.	88413.			0.90	0.	0.07	0.01	0.62	0.11	75.8	6.4	50.0	M	L
12	138	29369.	14346.	308	N-S	0.10	0.	0.07	0.05	1.10	0.26	11.2	19.5	20.6	M	M
	618	27926.	13534.			1.00	0.	0.07	0.05	0.60	0.17	11.2	19.5	20.6	D	M
13	162	27642.	24636.	0	E-W	0.75	0.	0.08	0.10	1.06	0.18	20.0	10.0	35.0	L	L
	662	27648.	24636.			0.75	0.	0.05	0.02	0.53	0.11	67.0	16.0	35.0	L	L
14	164	25515.	23704.	0	E-W	0.75	0.	0.07	0.05	1.13	0.17	15.0	11.0	35.8	L	M
	664	26775.	26202.			0.75	0.	0.06	0.03	0.60	0.10	15.0	11.0	37.8	L	L
15	165	113672.	96148.	140	E-W	0.50	0.	0.08	0.05	1.13	0.18	14.0	12.0	41.0	L	M
	665	113672.	94310.			0.40	0.	0.06	0.03	1.13	0.15	15.6	13.0	40.0	L	L
16	155	35010.	31788.	0	E-W	0.50	0.	0.27	0.11	1.06	0.34	75.0	10.0	95.0	L	M
	655	36393.	32880.			0.50	0.	0.09	0.04	0.90	0.27	80.0	75.0	95.0	L	L
MEAN ORIGINAL DESIGN		57041.	51300.	129.		0.54	1.	0.08	0.10	0.79	0.17	34.6	15.2	35.8		
MEAN REDESIGN		56608.	50324.	91.		0.56	2.	0.06	0.03	0.60	0.12	42.4	16.1	46.0		

P.A. BLDG NO. NO.	BLDG GLASS AREAS				SKYLIGHT AREA (SROOF)	GLASS SHADE COEFFICIENT				EXT SHADE	PROCESS LOADS				
	SO FT	ENVELO	SOUTH	NORTH		SOUTH	NORTH	EAST	WEST		GENERAL Kw/SF	RTUH/SF	SPECIAL Kw/SF	BTUH/SF	
1	168	6503.	21.	24.	31.	0.	1.00	1.00	1.00	1.00	YES	0.000	0.0	0.007	3.9
	668	2334.	8.	92.	0.	0.	1.00	0.00	1.00	1.00		0.000	0.0	0.006	0.4
2	158	3204.	14.	29.	34.	0.	0.65	0.65	0.65	0.65	YES	0.000	0.0	0.000	0.0
	658	10469.	20.	91.	8.	0.	0.80	0.80	0.80	0.80		0.001	0.0	0.000	0.0
3	160	871.	15.	43.	43.	0.	0.52	0.52	0.52	0.52		0.000	0.0	0.009	0.0
	660	2120.	20.	83.	17.	0.	0.88	0.52	0.00	0.00		0.000	0.0	0.011	0.0
4	161	2261.	14.	0.	2.	0.	0.00	0.80	0.80	0.80		0.000	0.0	0.000	0.0
	661	2640.	12.	46.	54.	0.	0.80	0.80	0.00	0.00		0.000	0.0	0.000	0.0
5	157	2311.	15.	10.	9.	0.	0.65	0.65	0.65	0.65	YES	0.001	0.0	0.011	0.0
	657	9411.	39.	87.	4.	0.	0.65	0.65	0.33	0.33		0.001	0.0	0.010	0.0
6	159	3448.	20.	21.	23.	0.	0.85	0.85	0.85	0.85	YES	0.001	0.0	0.013	10.9
	659	2652.	17.	27.	27.	3.	0.63	0.63	0.63	0.63		0.001	0.0	0.013	0.0
7	156	9377.	12.	31.	32.	0.	1.00	1.00	1.00	1.00		0.000	0.0	0.000	0.0
	656	10417.	11.	85.	15.	0.	0.50	1.00	0.00	0.00		0.000	0.0	0.000	0.0
8	8	6800.	13.	0.	0.	0.	0.00	0.00	0.48	0.48	YES	0.000	0.0	0.005	0.0
	508	3200.	11.	2.	2.	2.	1.00	1.00	0.57	0.57		0.000	0.0	0.005	0.0
9	163	3127.	12.	21.	23.	0.	1.00	1.00	1.00	1.00	YES	0.001	0.0	0.003	0.0
	663	969.	9.	44.	12.	0.	0.52	0.52	0.52	0.52		0.001	0.0	0.003	0.0
10	167	1650.	15.	46.	36.	0.	0.78	0.78	0.78	0.78	YES	0.001	0.0	0.003	0.0
	667	1650.	15.	46.	36.	0.	0.78	0.78	0.78	0.78		YES	0.001	0.0	0.003
11	166	8927.	18.	0.	22.	0.	0.00	0.65	0.62	0.60	YES	0.000	0.0	0.003	0.0
	666	7772.	18.	36.	31.	0.	0.37	0.51	0.51	0.51		0.000	0.0	0.003	0.0
12	138	2742.	32.	24.	0.	1.	0.52	0.00	0.52	0.52	YES	0.000	0.0	0.020	0.0
	638	2983.	34.	39.	0.	0.	0.81	0.00	0.81	0.81		0.000	0.0	0.012	0.0
13	162	2016.	16.	17.	17.	0.	0.65	0.65	0.65	0.65	YES	0.001	0.0	0.001	0.0
	662	2094.	14.	48.	52.	0.	0.65	0.65	0.00	0.00		YES	0.001	0.0	0.001
14	164	2927.	14.	41.	38.	0.	1.00	1.00	1.00	1.00	YES	0.000	0.0	0.002	104.3
	664	3596.	14.	27.	44.	0.	0.50	0.50	0.50	0.50		YES	0.000	0.0	0.002
15	165	17195.	21.	18.	18.	0.	1.00	1.00	1.00	1.00	YES	0.000	0.0	0.000	0.0
	665	14313.	19.	39.	40.	0.	1.00	1.00	1.00	1.00		YES	0.000	0.0	0.000
16	155	4450.	25.	34.	16.	0.	0.97	0.97	0.97	0.97	YES	0.000	0.0	0.017	0.0
	655	7744.	30.	31.	19.	0.	0.80	0.80	0.80	0.80		0.000	0.0	0.017	0.0
MEAN ORIGINAL DESIGN		4863.	17.	22.	22.	0.	0.81	0.82	0.78	0.78		0.000	0.0	0.006	7.4
MEAN REDESIGN		5273.	18.	51.	23.	0.	0.73	0.73	0.69	0.69		0.000	0.0	0.005	6.6

BEPS PHASE II KEY DATA BASE PARAMETER: MULTIFAMILY LOW RISE
LIGHTING SYSTEM

04-JAN-83
PAGE 3

	BDDG NO.	WATTS PER S.F.	ILLUM. LEVEL	LAMP TYPE (PERCENT TOTAL FLOOR AREA)								CONTROL TYPE (% TOTAL FLOOR AREA)							
				INC	TH	F	HG	HH	HPS	LPS	O	BKR	SW	LV	CPTR	PH	DIN	TC	O
1	168 668	0.4 1.1	11. 15.	95. 63.	0. 0.	5. 37.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	6. 10.	44. 79.	0. 0.	0. 0.	0. 0.	0. 0.	0. 11.	0. 0.
2	158 658	1.6 0.3	19. 20.	94. 43.	0. 0.	6. 57.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	11. 0.	89. 83.	0. 0.	0. 0.	0. 0.	0. 0.	0. 17.	0. 0.
3	160 660	0.9 0.3	18. 16.	100. 77.	0. 0.	0. 23.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	93. 100.	0. 0.	0. 0.	7. 0.	0. 0.	0. 0.	0. 0.
4	161 661	2.3 0.7	23. 31.	100. 40.	0. 0.	0. 59.	0. 0.	0. 0.	0. 1.	0. 0.	0. 0.	7. 16.	93. 83.	0. 0.	0. 0.	0. 1.	0. 0.	0. 0.	0. 0.
5	157 657	1.1 0.7	22. 23.	97. 0.	0. 0.	3. 100.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	92. 100.	0. 0.	0. 0.	0. 0.	0. 0.	8. 0.	0. 0.
6	159 659	1.5 0.9	20. 20.	79. 72.	0. 0.	21. 27.	0. 0.	0. 2.	0. 0.	0. 0.	0. 0.	0. 0.	81. 86.	0. 0.	0. 0.	0. 14.	0. 0.	19. 0.	0. 0.
7	156 656	1.1 0.1	30. 17.	99. 56.	0. 0.	1. 44.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	100. 100.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.
8	158 658	0.9 0.5	5. 7.	100. 32.	0. 0.	0. 65.	0. 2.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	100. 99.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.
9	163 663	1.7 0.9	16. 19.	95. 78.	0. 0.	5. 22.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	100. 100.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.
10	167 667	1.1 1.0	21. 21.	82. 84.	0. 0.	18. 16.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	100. 100.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.
11	166 666	0.7 0.4	10. 8.	96. 96.	0. 0.	4. 4.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	100. 100.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.
12	138 638	1.0 0.9	15. 15.	100. 100.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	100. 100.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.
13	162 662	1.0 0.6	45. 43.	33. 33.	0. 0.	67. 67.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	100. 100.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.
14	164 664	1.4 1.6	8. 16.	100. 100.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	100. 100.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.
15	165 665	0.8 0.8	53. 54.	89. 82.	0. 0.	11. 18.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	100. 100.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.
16	155 655	1.9 1.6	12. 11.	57. 72.	0. 0.	43. 28.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	100. 100.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.
MEAN ORIGINAL DESIGN		1.2	21.	80.	0.	11.	0.	0.	0.	0.	0.	2.	96.	0.	0.	0.	0.	2.	0.
MEAN REDESIGN		0.8	21.	64.	0.	36.	0.	0.	0.	0.	0.	2.	76.	0.	0.	1.	0.	2.	0.

P.A. NO.	BLDG NO.	SYSTEM ID		T-STAT SET PT.		COOL DAY HEAT	NIGHT HEAT	NIGHT HEAT	DEATH HARD	BLIGHT HEAT TO RA	DSCNG TEMP CTRL	EXHAUST AIR HEAT RECOVERY %VENT %EFF	SUPPLY CFM/SF PER INT.	CFM PER RHP	OUTSIDE AIR			ECOD TYPE
		INT PER	PER	%	CFM										CFM/PER			
1	16H	0	14	78.	72.	68.	YES	0.	0.	0.	0.	0.	0.49	0.00	1294.	15.	4660.	41.
	66H	15	16	78.	70.	70.	YES	6.	0.	0.	0.	0.	0.17	0.15	15654.	12.	1340.	13.
2	158	7	7	75.	74.	75.	YES	0.	0.	0.	0.	0.	0.13	0.14	3138.	31.	2750.	28.
	69H	0	7	0.	74.	65.	YES	0.	0.	0.	0.	0.	0.20	0.00	3236.	4.	400.	4.
3	160	0	14	78.	68.	68.	YES	0.	0.	0.	0.	0.	0.36	0.00	1440.	0.	0.	0.
	660	0	0	67.	67.	67.	YES	0.	0.	0.	0.	0.	0.00	0.00	0.	0.	0.	0.
4	161	14	14	78.	72.	72.	YES	0.	0.	0.	0.	0.	0.45	0.29	868.	3.	498.	4.
	661	8	8	78.	72.	72.	YES	0.	0.	0.	0.	0.	0.27	0.27	595.	7.	724.	6.
5	157	15	15	75.	70.	70.	YES	0.	0.	0.	0.	0.	1.51	0.51	4007.	0.	0.	0.
	657	0	10	75.	70.	70.	YES	5.	0.	0.	0.	0.	1.07	0.00	4208.	0.	0.	0.
6	159	10	10	78.	75.	75.	YES	0.	0.	0.	0.	0.	0.11	0.11	411.	30.	1259.	17.
	659	15	15	78.	75.	75.	YES	6.	0.	0.	0.	0.	0.88	0.61	1128.	13.	4134.	57.
7	156	0	0	55.	75.	75.	YES	0.	0.	0.	0.	0.	0.00	0.00	0.	0.	0.	0.
	656	0	0	55.	75.	75.	YES	0.	0.	0.	0.	0.	0.00	0.00	0.	0.	0.	0.
8	8	0	14	75.	70.	70.	YES	7.	0.	0.	0.	0.	0.84	0.00	2135.	0.	0.	0.
	50H	0	15	75.	70.	60.	YES	7.	0.	0.	0.	0.	9.46	0.00	3820.	0.	0.	0.
9	163	0	3	78.	70.	68.	YES	2.	0.	0.	0.	0.	0.54	0.00	2800.	0.	0.	0.
	663	3	3	78.	70.	65.	YES	8.	0.	0.	0.	0.	0.55	0.55	2859.	0.	0.	0.
10	167	0	0	55.	75.	75.	YES	0.	0.	0.	0.	0.	0.00	0.00	0.	0.	0.	0.
	667	0	0	55.	75.	75.	YES	0.	0.	0.	0.	0.	0.00	0.00	0.	0.	0.	0.
11	166	0	15	78.	75.	75.	YES	0.	0.	0.	0.	0.	0.50	0.00	670.	1.	300.	1.
	666	0	15	78.	75.	75.	YES	0.	0.	0.	0.	0.	0.80	0.00	1479.	0.	175.	1.
12	13H	0	0	0.	72.	72.	YES	0.	0.	0.	0.	0.	0.00	0.00	0.	0.	0.	0.
	638	0	0	55.	72.	72.	YES	0.	0.	0.	0.	0.	0.00	0.00	0.	0.	0.	0.
13	162	0	3	75.	70.	0.	YES	0.	0.	0.	0.	0.	1.25	0.00	1287.	10.	3089.	32.
	662	0	15	75.	70.	0.	YES	0.	0.	0.	0.	0.	1.17	0.00	4800.	0.	0.	0.
14	164	0	12	78.	68.	68.	YES	0.	0.	0.	0.	0.	0.70	0.00	1040.	0.	0.	0.
	664	0	15	78.	68.	68.	YES	0.	0.	0.	0.	0.	0.90	0.00	2353.	0.	0.	0.
15	165	0	14	78.	72.	68.	YES	0.	0.	0.	0.	0.	0.64	0.00	3119.	2.	1235.	4.
	665	0	15	78.	72.	68.	YES	10.	0.	0.	0.	0.	0.62	0.00	3591.	2.	1142.	4.
16	155	0	3	75.	72.	72.	NO	0.	5.	0.	0.	0.	0.60	0.00	2536.	7.	1426.	24.
	655	0	15	75.	72.	72.	NO	10.	5.	0.	0.	0.	0.64	0.00	7880.	8.	1572.	25.
MEAN ORIGINAL DESIGN				69.	72.	67.		5.	5.	0.	0.	0.	0.51	0.26	1547.	6.	951.	10.
MEAN REDSIGN				67.	72.	66.		7.	5.	0.	0.	0.	0.48	0.39	3225.	3.	593.	7.

P.A. NO.	RTON, FEE	CHEMICAL COOLING COOL	HEAT RECOVERY FEE	HEAT RECOVERY TYPE	HEAT RECOVERY TYPE	HEAT RECOVERY TYPE	HEAT RECOVERY TYPE	HEAT RECOVERY TYPE	HEAT RECOVERY TYPE	HEAT RECOVERY TYPE	HEAT RECOVERY TYPE	HEAT RECOVERY TYPE	HEAT RECOVERY TYPE	HEAT RECOVERY TYPE	HEAT RECOVERY TYPE
1	160 660	2.5 2.1	0.4 1.0												
2	150 650	1.3 1.3	0.5 0.5												
3	160 660	1.8 0.0	0.8 1.0												
4	141 651	2.7 5.0	0.7 0.5												
5	151 651	2.1 2.7	0.0 0.0												
6	150 650	1.7 2.4	0.0 0.0												
7	150 650	0.0 0.0	0.0 0.0												
8	0 604	2.1 2.1	1.0 0.0												
9	161 661	1.0 2.0	1.0 0.0												
10	167 667	0.0 0.0	1.0 1.0												
11	166 666	2.0 2.1	1.0 1.0												
12	136 636	0.0 0.0	1.0 1.0												
13	142 642	2.1 1.7	1.0 0.0												
14	163 663	2.1 2.1	1.0 0.1												
15	160 660	2.0 2.4	1.0 1.0												
16	150 650	1.6 1.0	0.8 0.0												
REF. 10056 11		2.0	0.0												
REF. 10056 11		1.0	0.0												

REPS PHASE II KEY DATA BASE PARAMETER: MULTIFAMILY HIGH RISE
ENVELOPE

04-124-83
PAGE 1

P.A. NO.	BIDG NO.	FLOOR AREA		ORIENT. DEG. FRM NORTH	MAJOR ORIENT.	WINTER INF. (ACH)	WALL BELCM GRADE	U-VALUES				BLDG MASS (LB/SF)			BLDG COLOR	
		GROSS	NET					WALL	ROOF	GLASS	COMPOSITE	WALL	ROOF	FLOOR	WALL	ROOF
17	7A	121058.	119682.	0		0.50	0.	0.09	0.10	0.58	0.15	75.0	64.0	57.0	M	M
	576	130300.	127718.	0		0.10	0.	0.07	0.08	0.39	0.11	82.0	64.0	57.0	M	M
18	81	46120.	45084.	0		0.60	3.	0.23	0.07	0.51	0.21	60.5	78.0	75.0	L	M
	581	45848.	35920.	0		0.60	0.	0.05	0.03	0.45	0.09	67.0	78.0	75.0	L	L
19	42	127470.	116370.	0		0.50	0.	0.06	0.05	0.61	0.24	49.6	48.0	46.0	D	D
	542	127470.	116564.	0		0.50	0.	0.06	0.05	0.54	0.16	41.9	48.0	34.0	D	D
20	119	149930.	132303.	45	E-W	0.60	12.	0.20	0.10	0.57	0.31	65.1	90.0	72.0	M	D
	619	146002.	105660.	0		0.45	6.	0.06	0.05	0.50	0.12	90.8	95.0	95.0	D	D
21	12	111264.	108901.	341	N-S	0.47	3.	0.11	0.05	0.52	0.15	73.0	17.8	45.0	M	D
	512	108500.	106699.	0		0.50	3.	0.06	0.03	0.40	0.10	93.0	17.8	45.0	M	D
22	11	131200.	109900.	3	N-S	1.55	2.	0.07	0.16	0.62	0.19	77.0	117.0	100.0	M	M
	511	135224.	115410.	3		0.83	2.	0.04	0.06	0.58	0.12	53.4	99.7	100.0	L	L
23	21	131600.	113400.	3	N-S	0.50	8.	0.10	0.10	0.60	0.27	126.0	108.0	96.0	L	L
	521	147700.	134300.	3	E-W	0.50	15.	0.06	0.06	0.60	0.22	80.8	110.0	96.0	L	L
24	28	152300.	144311.	320	N-S	0.50	0.	0.24	0.11	1.10	0.42	112.0	93.0	93.0	M	M
	526	150106.	112054.	0	E-W	0.35	0.	0.12	0.11	0.60	0.22	111.7	100.0	100.0	L	L
25	37	45670.	41970.	33	N-S	1.00	0.	0.07	0.08	1.10	0.09	98.9	69.0	48.0	M	M
	537	47360.	43990.	0		0.50	14.	0.06	0.06	0.65	0.08	96.3	69.0	48.0	M	L
MEAN ORIGINAL DESIGN		112957.103547.		83.		0.69	3.	0.13	0.09	0.69	0.23	84.1	76.1	70.2		
MEAN REDESIGN		115390.99813.		1.		0.48	4.	0.07	0.06	0.52	0.14	79.7	75.7	72.2		

PCPS PHASE II KEY DATA BASE PARAMETER: MULTIFAMILY HIGH RISE
ENVELOPE

04-JAN-83
PAGE 2

P.A. NO.	BLDG NO.	BLDG GLASS AREA				SKYLIGHT AREA (SROOF)	GLASS SHADE COEFFICIENT				EXT SHADE	PROCESS LOADS			
		SQ FT	ELEV	% SOUTH	% NORTH		SOUTH	NORTH	EAST	WEST		GENERAL KW/SF	BTUH/SF	SPECIAL KW/SF	BTUH/SF
17	76	9084.	15.	30.	24.	1.	0.82	0.82	0.82	0.82		0.001	0.0	0.001	0.0
	576	8763.	17.	20.	38.	2.	0.72	0.72	0.72	0.72		0.001	0.0	0.001	0.0
18	81	3024.	14.	8.	3.	0.	0.88	0.88	0.88	0.88	YES	0.001	0.0	0.000	0.0
	581	2621.	11.	46.	6.	0.	0.80	0.80	0.80	0.80		0.000	0.0	0.000	0.0
19	42	18811.	42.	20.	40.	0.	0.81	0.81	0.81	0.81	YES	0.000	0.0	0.011	9.4
	542	10290.	23.	17.	23.	0.	0.81	0.81	0.81	0.81	YES	0.000	0.0	0.011	6.3
20	119	26296.	40.	33.	30.	0.	0.51	0.51	0.51	0.51	YES	0.000	0.0	0.002	0.0
	619	10240.	14.	50.	0.	0.	0.90	0.90	0.90	0.90	YES	0.000	0.0	0.002	0.0
21	12	7930.	16.	5.	3.	0.	0.57	0.57	0.57	0.57		0.000	0.0	0.000	0.0
	512	8300.	15.	0.	0.	0.	0.00	0.57	0.57	0.57		0.000	0.0	0.000	0.0
22	11	13019.	23.	5.	5.	0.	0.66	0.67	0.62	0.62		0.000	0.0	0.000	0.3
	511	12442.	17.	47.	1.	0.	0.55	0.55	0.55	0.55	YES	0.000	0.0	0.000	0.0
23	21	30320.	44.	27.	20.	0.	0.42	0.42	0.42	0.42		0.000	0.0	0.008	0.0
	521	22660.	36.	80.	13.	0.	0.75	0.75	0.75	0.75	YES	0.000	0.0	0.008	0.0
24	28	18638.	26.	6.	6.	0.	0.53	0.53	0.53	0.53	YES	0.000	0.0	0.000	47.1
	528	15131.	27.	42.	41.	0.	0.53	0.53	0.53	0.53	YES	0.000	0.0	0.000	47.8
25	37	865.	6.	21.	28.	0.	0.71	0.71	0.71	0.71		0.000	0.0	0.006	0.0
	517	909.	4.	27.	68.	2.	0.81	0.81	0.81	0.81	YES	0.001	0.0	0.006	0.0
MEAN ORIGINAL DESIGN		14221.	25.	17.	18.	0.	0.66	0.66	0.65	0.65		0.000	0.0	0.003	6.3
MEAN REDSIGN		10151.	18.	37.	21.	0.	0.73	0.69	0.72	0.68		0.000	0.0	0.003	6.0

REPS PHASE II KEY DATA BASE PARAMETER: MULTIFAMILY HIGH RISE
LIGHTING SYSTEM

04-JAN-83
PAGE 3

P.A. NO.	BLDG NO.	WATTS PER S.F.	ILLUM. LEVEL	LAMP TYPE (PERCENT TOTAL FLOOR AREA)								CONTROL TYPE (% TOTAL FLOOR AREA)							
				INC	TH	F	HG	MH	HPS	LPS	O	HKR	SW	LV	CPTR	PH	UIN	IC	U
17	76	1.9	16.	80.	0.	20.	0.	0.	0.	0.	0.	18.	80.	0.	0.	0.	0.	0.	0.
	576	1.6	21.	56.	0.	40.	0.	0.	2.	0.	0.	8.	76.	0.	0.	13.	0.	0.	0.
18	81	0.9	12.	100.	0.	0.	0.	0.	0.	0.	0.	31.	69.	0.	0.	0.	0.	0.	0.
	581	1.0	15.	69.	0.	31.	0.	0.	0.	0.	0.	11.	89.	0.	0.	0.	0.	0.	0.
19	42	0.9	5.	97.	0.	2.	0.	1.	0.	0.	0.	22.	77.	0.	0.	0.	0.	1.	0.
	542	0.8	8.	25.	0.	56.	19.	0.	0.	0.	0.	5.	95.	0.	0.	0.	0.	0.	0.
20	119	1.0	15.	96.	0.	4.	0.	0.	0.	0.	0.	0.	95.	0.	0.	0.	0.	5.	0.
	619	0.9	17.	56.	0.	42.	0.	0.	0.	0.	0.	5.	85.	0.	0.	0.	0.	8.	0.
21	12	1.5	30.	61.	0.	39.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	512	1.5	30.	65.	0.	35.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
22	11	0.8	12.	74.	0.	26.	0.	0.	0.	0.	0.	10.	90.	0.	0.	0.	0.	0.	0.
	511	0.4	8.	1.	0.	58.	0.	0.	0.	0.	0.	8.	51.	0.	0.	0.	0.	0.	0.
23	21	0.7	34.	58.	0.	42.	0.	0.	0.	0.	0.	10.	90.	0.	0.	0.	0.	0.	0.
	521	1.1	41.	0.	0.	98.	2.	0.	0.	0.	0.	6.	77.	0.	0.	0.	2.	16.	0.
24	28	0.5	13.	84.	0.	16.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	528	0.4	7.	0.	0.	100.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
25	37	2.1	58.	0.	0.	96.	4.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	537	0.7	44.	0.	0.	88.	0.	5.	7.	0.	0.	0.	99.	0.	0.	0.	0.	0.	0.
MEAN ORIGINAL DESIGN				1.2	22.	72.	0.	27.	0.	0.	0.	10.	89.	0.	0.	0.	0.	1.	0.
MEAN REDFSIGN				0.9	21.	30.	0.	61.	2.	1.	1.	5.	86.	0.	0.	1.	0.	3.	0.

REPS PHASE II KEY DATA BASE PARAMETER: MULTIFAMILY HIGH RISK
SECONDARY SYSTEM

04-JAN-83
PAGE 4

P.A. NO.	BLDG NO.	SYSTEM ID		T-STAT SET PT.				DEAD HAND	HEAT TO RA	WLGHT TEMP CTRL	DSCHG HEAT RECOVERY %VENT %EFF	EXHAUST AIR		SUPPLY		CFM PEP RHP	OUTSIDE AIR			ECON TYPE
		INT	PEP	COOL	DAY	NIGHT	NIGHT							CFM/SF	PER,INT.		%	CFM	CFM/PEP	
17	76	0	14	78.	75.	0.	YES	0.	0.			0.	0.	0.17	0.00	2112.	32.	6324.	78.	
	576	0	14	78.	75.	75.	YES	0.	0.			0.	0.	0.12	0.00	2128.	3.	508.	2.	
18	81	0	14	0.	70.	70.	YES	0.	0.			0.	0.	0.40	0.00	1858.	30.	5410.	68.	
	581	0	3	78.	70.	65.	YES	0.	0.			0.	0.	0.53	0.00	2098.	7.	1250.	16.	
19	42	0	3	78.	72.	72.	YES	4.	0.			0.	0.	0.88	0.00	2575.	16.	16236.	67.	
	542	0	3	78.	72.	72.	YES	4.	0.			0.	0.	0.82	0.00	2635.	12.	11117.	46.	
20	119	7	7	52.	75.	75.	YES	0.	0.			0.	0.	0.09	1.08	2494.	65.	17073.	74.	
	619	7	14	55.	75.	75.	YES	0.	0.			0.	0.	0.08	0.70	2656.	62.	14318.	62.	
21	12	0	14	0.	75.	75.	YES	0.	0.			0.	0.	0.60	0.00	2848.	12.	7545.	31.	
	512	0	15	80.	75.	75.	YES	0.	0.			0.	0.	0.51	0.00	2225.	6.	3110.	13.	
22	11	3	10	78.	75.	75.	YES	0.	0.			0.	0.	1.19	0.62	1975.	4.	5485.	28.	
	511	7	10	78.	75.	75.	YES	0.	0.			63.	95.	0.83	1.82	3330.	6.	5590.	28.	
23	21	0	10	78.	72.	70.	YES	0.	0.			0.	0.	1.21	0.00	5108.	2.	3075.	14.	
	521	0	15	78.	72.	70.	YES	6.	0.	NIT		0.	0.	0.96	0.00	5161.	2.	2146.	10.	
24	28	2	14	75.	75.	0.	YES	4.	0.			0.	0.	0.75	0.47	1796.	22.	22268.	102.	
	528	0	14	78.	72.	72.	YES	6.	0.			0.	0.	0.67	0.00*****		22.	16598.	76.	
25	37	0	15	75.	70.	60.	YES	5.	60.			100.	30.	1.19	0.00	3827.	15.	7462.	11.	
	537	0	15	75.	70.	60.	YES	0.	60.			100.	30.	1.08	0.00	3816.	15.	7441.	11.	
MEAN ORIGINAL DESIGN				57.	73.	55.		4.	60.			11.	3.	0.72	0.72	2732.	22.	10097.	47.	
MEAN REDESIGN				75.	73.	71.		5.	60.			18.	14.	0.62	1.2652473.		15.	6898.	29.	

RRPS PHASE II KEY DATA BASE PARAMETERS: MULTIFAMILY HIGH RISE
PRIMARY SYSTEM

06-JAN-83
PAGE 5

P.A. NO.	BLDG. NO.	CHILLED COOLING COP	HEATING EFF.	HEAT RECOVERY	HEAT PUMP TYPE	HP HEATING COP	COOLING FUEL TYPE	HOT WATER STORAGE (BTU/RTU CAP)	AUX. KW COOLING VAR.	CONST	AUX. KW HEATING VAR.	CONST	S.F. PER TON	HEATING BTU PER SF
17	76 576	1.6 2.6	0.8 0.8			0.0 0.0	E E	0. 0.	0. 4.	0. 0.	5. 0.	5. 2.	559. 569.	34. 8.
18	81 591	1.7 2.1	0.8 1.0			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	1. 0.	0. 0.	997. 1412.	27. 11.
19	42 542	1.9 1.8	0.8 0.8			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	416. 423.	62. 44.
20	110 614	1.7 1.4	0.8 0.8			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	7. 4.	0. 0.	295. 351.	58. 33.
21	12 512	2.9 1.8	1.0 1.0			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	788. 705.	37. 5.
22	11 511	1.4 3.8	0.8 0.8			0.0 0.0	E E	0. 0.	17. 6.	41. 19.	17. 7.	1. 2.	426. 1072.	48. 21.
23	21 521	4.3 2.8	1.0 1.0		11	0.0 3.5	E E	0. 0.	48. 13.	0. 22.	0. 0.	0. 0.	389. 2036.	25. 0.
24	28 528	1.9 1.9	0.8 0.8			0.0 0.0	E E	0. 0.	2. 0.	1. 0.	14. 5.	0. 0.	504. 1045.	35. 12.
25	37 537	4.4 4.4	0.0 0.0		11 11	3.4 3.4	E E	0. 81150.	0. 0.	19. 19.	0. 0.	0. 0.	0. 0.	0. 0.
MEAN ORIGINAL DESIGN		2.8	0.9	0		3.4		0.	7.	7.	5.	1.	547.	36.
MEAN REDESIGN		2.5	0.9	0		3.4		81150.	3.	7.	2.	0.	952.	17.

P.A. NO.	BLDG NO.	FLOOR AREA		ORIENT. DEG. FRK NORTH	MAJOR ORIENT.	WINTER INF. (ACH)	WALL BELOW GRADE	U-VALUES				BLDG MASS (LB/SF)			BLDG COLOR	
		GROSS	NET					WALL	ROOF	GLASS	COMPOSITE	WALL	ROOF	FLOOR	WALL	ROOF
	70	110700.	110694.	0		0.25	34.	0.08	0.05	0.50	0.11	80.0	90.0	100.0	M	M
	570	111000.	110700.	0		0.11	34.	0.08	0.05	0.28	0.08	80.0	90.0	100.0	M	M
	57	62370.	56605.	0	E-W	0.50	0.	0.16	0.05	0.64	0.13	69.0	27.0	48.0	M	L
	557	67400.	60273.	0		0.25	0.	0.07	0.09	0.60	0.13	81.4	74.0	89.0	M	L
	72	52550.	39517.	0	E-W	0.80	16.	0.16	0.11	0.61	0.18	80.0	85.0	100.0	M	L
	572	46600.	37334.	0	E-W	0.80	28.	0.08	0.07	0.59	0.13	89.2	105.0	100.0	L	L
	1	47860.	38237.	344		0.50	7.	0.07	0.08	0.55	0.13	49.0	91.0	80.0	D	L
	501	50710.	35470.	12		0.50	13.	0.05	0.04	0.55	0.08	49.0	93.0	80.0	D	L
	35	131700.	120480.	0	E-W	0.40	15.	0.11	0.08	0.58	0.12	86.4	82.0	47.0	M	L
	535	124600.	112113.	0		0.40	21.	0.03	0.02	0.29	0.04	82.0	83.0	53.0	M	L
	6	40371.	39325.	22		0.75	6.	0.10	0.10	0.58	0.14	129.1	57.0	71.5	L	L
	506	38040.	30224.	342	E-W	0.75	19.	0.05	0.05	0.58	0.09	162.9	64.2	71.5	L	L
	139	15780.	14268.	0		0.50	12.	0.07	0.05	0.64	0.09	8.0	7.0	10.0	M	M
	639	15085.	14323.	20		0.50	28.	0.05	0.04	0.64	0.16	8.0	7.0	10.0	M	M
	76	26027.	24962.	1	E-W	0.50	0.	0.34	0.09	1.00	0.23	77.0	24.4	47.0	M	D
	520	31552.	26846.	1	E-W	0.75	12.	0.11	0.04	0.55	0.10	118.1	5.2	47.0	L	M
	114	41190.	34106.	0		0.20	0.	0.08	0.13	1.06	0.15	30.0	38.0	39.0	M	D
	614	41570.	33867.	0		0.20	0.	0.07	0.07	0.61	0.09	76.0	12.0	39.0	M	D
	127	4261.	4030.	0	W-S	1.00	0.	0.08	0.05	1.13	0.23	12.4	6.5	4.3	L	M
	627	4421.	4157.	0		1.00	0.	0.08	0.05	1.13	0.23	12.4	44.5	43.1	M	M
	149	12607.	25267.	328	N-S	1.20	0.	0.08	0.05	0.89	0.15	12.9	9.3	14.0	L	D
	649	26450.	26000.	0		0.80	0.	0.05	0.03	0.50	0.07	13.5	15.0	14.0	L	L
MEAN ORIGINAL DESIGN		51404.	46171.	63.		0.60	8.	0.12	0.08	0.74	0.15	57.6	47.0	51.0		
MEAN REDESIGN		50694.	44665.	34.		0.55	14.	0.06	0.05	0.57	0.11	70.2	53.9	58.8		

P.A. NO.	BLDG NO.	BLDG GLASS AREAS				SKYLIGHT AREA (SQ FT)	GLASS SHADE COEFFICIENT				EXT SHADE	PROCESS LOADS			
		SQ FT	EAST	SOUTH	NORTH		SOUTH	NORTH	EAST	WEST		GENERAL Kw/SF	GENERAL BTUH/SF	SPECTAL Kw/SF	SPECTAL BTUH/SF
8	79	6745.	21.	10.	8.	1.	0.62	0.62	0.43	0.62		0.001	0.0	0.000	4.7
	579	5648.	14.	11.	10.	1.	0.23	0.23	0.23	0.23	YES	0.001	0.0	0.000	4.7
9	57	4030.	13.	33.	23.	0.	0.25	0.25	0.25	0.25		0.001	0.0	0.002	0.0
	557	5192.	14.	71.	14.	2.	0.50	0.50	0.00	0.50	YES	0.001	0.0	0.000	5.3
10	72	3369.	22.	22.	37.	0.	0.89	0.89	0.89	0.89		0.001	0.0	0.003	9.9
	572	2614.	22.	48.	24.	0.	0.89	0.89	0.89	0.89	YES	0.001	0.0	0.003	11.1
11	1	4252.	20.	12.	20.	1.	0.73	0.84	0.84	0.76		0.001	0.0	0.002	6.3
	501	2858.	17.	26.	25.	0.	0.84	0.84	0.84	0.84	YES	0.001	0.0	0.002	5.9
12	35	10079.	24.	37.	34.	0.	0.46	0.46	0.46	0.46	YES	0.000	0.0	0.002	0.0
	535	11207.	26.	76.	0.	0.	0.14	0.14	0.14	0.14	YES	0.000	0.0	0.003	0.0
13	6	3316.	16.	31.	17.	0.	0.90	0.90	0.90	0.90	YES	0.000	0.0	0.000	0.0
	506	3182.	18.	79.	8.	0.	0.60	0.60	0.60	0.60	YES	0.000	0.0	0.000	0.0
14	139	1393.	18.	26.	26.	0.	0.75	0.75	0.75	0.75	YES	0.000	0.0	0.000	24.4
	639	3108.	43.	76.	14.	0.	0.86	0.86	0.86	0.86	YES	0.000	0.0	0.000	10.1
15	26	2315.	14.	24.	29.	0.	0.56	0.56	0.56	0.56		0.000	0.0	0.000	59.9
	526	3577.	24.	23.	64.	0.	0.58	0.58	0.58	0.58	YES	0.000	0.0	0.000	0.0
16	114	2121.	12.	24.	24.	0.	0.71	0.64	0.66	0.66	YES	0.000	0.0	0.001	5.1
	614	2231.	14.	19.	49.	0.	0.51	0.56	0.57	0.57	YES	0.000	0.0	0.001	5.1
17	127	863.	29.	27.	1.	0.	0.65	0.65	0.65	0.65	YES	0.000	0.0	0.007	0.0
	627	919.	23.	22.	0.	10.	0.65	0.00	0.65	0.69	YES	0.000	0.0	0.006	0.0
18	149	2755.	22.	3.	3.	2.	0.73	0.73	0.73	0.73	YES	0.000	0.0	0.000	51.5
	649	1583.	11.	29.	7.	2.	0.52	0.52	0.52	0.52	YES	0.000	0.0	0.000	59.0
MEAN ORIGINAL DESIGN		3753.	19.	23.	20.	0.	0.66	0.66	0.65	0.66		0.000	0.0	0.002	14.7
MEAN REDFSIGN		3847.	21.	44.	20.	1.	0.57	0.57	0.59	0.58		0.001	0.0	0.001	9.2

BEPS PHASE II KEY DATA BASE PARAMETER: NURSING HOMES
LIGHTING SYSTEM

04-JAN-83
PAGE 3

P.A. NO.	BLDG NO.	WATIS PER S.F.	ILLUM. LEVEL	LAMP TYPE (PERCENT TOTAL FLOOR AREA)								CONTROL TYPE (% TOTAL FLOOR AREA)							
				INC	TH	F	HG	HM	HFS	LPS	U	RRR	S*	LV	CPTR	PH	DIA	IC	U
8	79	1.2	32.	0.	0.	99.	1.	0.	0.	0.	0.	0.	99.	0.	0.	0.	0.	1.	0.
	579	1.1	30.	0.	0.	99.	0.	0.	1.	0.	0.	0.	99.	0.	0.	0.	0.	1.	0.
9	57	1.3	11.	60.	0.	40.	0.	0.	0.	0.	0.	35.	65.	0.	0.	0.	0.	0.	0.
	557	0.9	18.	0.	0.	100.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
10	72	1.4	34.	15.	0.	85.	0.	0.	0.	0.	0.	2.	98.	0.	0.	0.	0.	0.	0.
	572	1.4	18.	21.	0.	79.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
11	1	1.5	26.	29.	0.	71.	0.	0.	0.	0.	0.	6.	86.	0.	0.	0.	8.	0.	0.
	501	1.0	27.	3.	0.	97.	0.	0.	0.	0.	0.	0.	98.	0.	0.	0.	2.	0.	0.
12	35	1.7	36.	12.	0.	88.	0.	0.	0.	0.	0.	39.	61.	0.	0.	0.	0.	0.	0.
	535	1.3	31.	0.	0.	91.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
13	6	0.9	31.	35.	0.	65.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	506	0.4	21.	11.	0.	89.	0.	0.	0.	0.	0.	22.	78.	0.	0.	0.	0.	0.	0.
14	139	2.2	51.	51.	0.	49.	0.	0.	0.	0.	0.	9.	83.	0.	0.	0.	8.	0.	0.
	639	1.3	29.	36.	0.	64.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
15	26	1.0	40.	20.	0.	80.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	526	0.8	28.	26.	0.	74.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
16	114	3.3	25.	51.	0.	49.	0.	0.	0.	0.	0.	3.	97.	0.	0.	0.	0.	0.	0.
	614	1.3	17.	16.	0.	84.	0.	0.	0.	0.	0.	12.	88.	0.	0.	0.	0.	0.	0.
17	127	1.4	28.	84.	0.	16.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	627	0.8	28.	78.	0.	22.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
18	149	2.0	51.	40.	0.	60.	0.	0.	0.	0.	0.	0.	69.	0.	0.	0.	0.	31.	0.
	649	0.7	40.	58.	0.	41.	0.	0.	0.	0.	0.	0.	41.	0.	0.	0.	58.	0.	0.
MEAN ORIGINAL DESIGN				1.6	33.	36.	0.	64.	0.	0.	0.	9.	87.	0.	0.	0.	1.	3.	0.
MEAN REDESIGN				1.0	26.	24.	0.	76.	0.	0.	0.	3.	91.	0.	0.	0.	5.	0.	0.

REFS PHASE II KEY DATA BASE PARAMETER: NURSING HOMES
SECONDARY SYSTEM

04-JAN-83
PAGE 4

P.A. NO.	BLDG NO.	SYSTEM ID		T-STAT SET PT.				LEAD HAND	W/LIGHT DSCNG		EXHAUST AIR		SUPPLY		CFM PER BHP	OUTSIDE AIR			ECON TYPE
		INT	FFM	COOL	DAY	NIGHT	NIGHT		HEAT	TEMP	HEAT	RECOVERY	CFM/SF	PER,INT.		%	CFM	CFM/PER	
8	74	3	3	80.	75.	75.	YES	0.	30.		92.	72.	0.58	0.53	418.	90.	56646.	227.	
	574	3	3	80.	75.	75.	YES	0.	30.	NU	96.	70.	0.58	0.53	533.	54.	33699.	135.	
9	57	3	14	80.	75.	75.	YES	0.	0.		0.	0.	1.33	0.72	1543.	33.	22861.	86.	
	557	10	10	80.	75.	75.	YES	0.	0.		0.	0.	0.90	1.15	1944.	18.	9734.	35.	
10	72	7	10	75.	75.	72.	YES	0.	0.		0.	0.	1.15	3.02	1800.	26.	13034.	99.	
	572	3	10	78.	74.	72.	YES	4.	0.		85.	60.	0.73	0.84	1400.	43.	12175.	92.	
11	1	14	14	7.	72.	72.	YES	0.	0.		42.	65.	0.73	1.06	2114.	15.	4260.	36.	
	501	7	14	70.	75.	75.	YES	0.	0.		0.	0.	0.54	0.50	3390.	10.	1859.	9.	55.
12	35	0	5	75.	70.	70.	YES	5.	70.	NU	0.	0.	0.95	0.00	460.	44.	50556.	166.	ENTH
	535	0	12	78.	70.	70.	YES	8.	30.		0.	0.	0.72	0.00	2057.	15.	11999.	33.	
13	6	7	7	0.	78.	68.	YES	0.	0.		0.	0.	0.81	1.01	3143.	62.	20452.	128.	
	506	7	7	75.	75.	68.	YES	0.	0.		0.	0.	0.43	0.28	6622.	45.	5656.	47.	
14	139	7	7	75.	75.	60.	YES	0.	0.		0.	0.	0.99	0.54	5119.	29.	3954.	101.	
	639	7	7	70.	70.	55.	YES	0.	0.		0.	0.	0.71	0.36	2974.	10.	976.	25.	
15	26	0	14	78.	78.	78.	YES	0.	0.		0.	0.	1.25	0.00	2218.	56.	17315.	115.	
	526	0	12	78.	78.	78.	YES	0.	0.	NU	0.	0.	0.76	0.00	2377.	26.	5312.	34.	ENTH
16	114	0	14	78.	73.	73.	YES	4.	0.		0.	0.	0.96	0.00	1932.	25.	8230.	57.	
	614	0	15	78.	73.	73.	YES	5.	0.		22.	80.	0.95	0.00	1964.	24.	7734.	54.	
17	127	0	7	55.	70.	70.	YES	0.	0.		0.	0.	0.62	0.00	4145.	0.	0.	0.	
	627	7	7	55.	70.	70.	YES	0.	0.		0.	0.	0.63	0.13	4050.	0.	0.	0.	
18	149	0	15	75.	75.	70.	YES	5.	0.		0.	0.	0.82	0.00	3432.	19.	4021.	101.	
	649	0	7	80.	70.	70.	YES	10.	0.		0.	0.	0.36	0.00	2082.	0.	0.	0.	
MEAN ORIGINAL DESIGN				61.	74.	71.		5.	50.		12.	12.	0.93	1.14	2393.	36.	18303.	101.	
MEAN REDESIGN				75.	73.	71.		7.	30.		18.	19.	0.66	0.54	2677.	22.	8104.	42.	

PEFS PHASE II KEY DATA BASE PARAMETER: NURSING HOMES
PRIMARY SYSTEM

OK-JAN-83
PAGE 5

P.A. NO.	BLDG. NO.	CHILLER COOLING COP	HEATING EFF.	HEAT RECOVERY	HEAT PUMP TYPE	HP HEATING COP	COOLING FUEL TYPE	HOT WATER STORAGE (BTU/RTU CAP)	AUX. KW COOLING VAR.	AUX. KW COOLING CONST	AUX. KW HEATING VAR.	AUX. KW HEATING CONST	S.F. PER TON	HEATING BTU PER SF
8	79 579	4.6 4.6	0.8 0.8			0.0 0.0	E E	0. 0.	35. 35.	24. 24.	5. 5.	0. 0.	329. 329.	48. 48.
9	57 557	2.0 3.4	1.0 0.7			0.0 0.0	E E	0. 0.	0. 0.	0. 9.	0. 3.	0. 0.	139. 978.	64. 60.
10	77 577	2.6 4.1	0.8 0.8			0.0 0.0	E E	0. 0.	26. 34.	0. 0.	26. 18.	0. 0.	298. 180.	185. 116.
11	1 501	2.8 2.2	0.8 0.8			0.0 0.0	E E	0. 0.	0. 0.	5. 3.	2. 2.	1. 1.	236. 288.	64. 68.
12	15 515	1.9 4.1	1.0 1.0			0.0 0.0	E E	0. 0.	104. 0.	5. 84.	34. 34.	6. 6.	291. 612.	83. 46.
13	5 506	2.5 2.0	0.8 0.9			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	4. 0.	0. 0.	413. 374.	40. 13.
14	114 614	0.0 4.0	0.9 0.8			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 2.	0. 0.	0. 0.	31. 10.
15	26 526	2.9 3.3	0.9 0.8			0.0 0.0	E E	0. 0.	0. 22.	0. 11.	0. 12.	0. 0.	301. 581.	68. 25.
16	114 614	2.1 1.9	1.0 1.0			0.0 0.0	E E	0. 0.	0. 0.	0. 1.	0. 0.	0. 0.	377. 450.	35. 29.
17	127 627	0.0 0.0	0.8 0.8			0.0 0.0		0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	33. 30.
18	149 649	2.2 0.0	0.8 1.0			0.0 0.0	E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	391. 0.	11. 3.
MEAN ORIGINAL DESIGN		2.3	0.9	0		0.0		0.	15.	3.	6.	1.	330.	60.
MEAN REDESIGN		2.7	0.9	0		0.0		0.	8.	17.	7.	1.	500.	41.

REPS PHASE II KEY DATA BASE PARAMETER: HOTEL/HOTEL
ENVELOPE

04-JAN-83
PAGE 1

P.A. NO.	BLDG NO.	FLOOR AREA		ORIENT. DEG. FRM NORTH	MAJOR ORIENT.	WINTER INF. (ACH)	WALL BELOW GRADE	U-VALUES				BLDG MASS (LB/SF)			BLDG COLOR	
		GROSS	NET					WALL	ROOF	GLASS	COMPOSITE	WALL	ROOF	FLOOR	WALL	ROOF
1	56	16750.	13850.	44	N-S	0.30	0.	0.06	0.04	0.65	0.10	5.0	10.0	40.0	L	M
	556	17000.	13203.	333	E-W	0.20	0.	0.05	0.03	0.38	0.06	30.0	10.0	40.0	M	L
2	71	129700.	115920.	0	E-W	0.80	4.	0.06	0.05	0.55	0.17	70.0	22.0	33.0	L	M
	571	113900.	104657.	0	E-W	0.60	16.	0.04	0.05	0.53	0.09	110.0	100.0	100.0	M	M
3	40	32513.	31577.	18	N-S	0.00	0.	0.13	0.05	0.60	0.12	36.9	8.0	58.0	L	M
	540	40852.	39592.	18	N-S	0.60	13.	0.07	0.05	0.63	0.09	34.8	4.0	58.0	L	M
4	14	39470.	29659.	30	N-S	0.50	3.	0.12	0.12	0.58	0.18	73.5	75.1	72.3	D	M
	514	31000.	27200.	0	E-W	0.50	46.	0.08	0.05	0.50	0.13	73.5	75.1	72.3	D	L
5	107	45104.	43273.	315	E-W	0.75	0.	0.66	0.06	1.13	0.40	70.0	66.5	52.0	M	D
	607	45104.	43306.	315	E-W	0.75	0.	0.09	0.05	0.58	0.10	61.0	2.8	52.0	L	M
6	116	46044.	38400.	45	E-W	0.80	0.	0.19	0.20	0.65	0.33	55.8	75.0	75.0	M	M
	616	47200.	37161.	0	E-W	0.80	0.	0.18	0.13	0.61	0.24	72.8	85.0	75.0	M	T.
7	117	160400.	140800.	0	E-W	0.00	0.	0.28	0.20	0.57	0.36	70.0	90.0	88.0	L	M
	617	141716.	123917.	0	E-W	0.00	0.	0.06	0.08	0.57	0.20	20.0	92.0	88.0	L	M
MEAN ORIGINAL DESIGN		47140.	59068.	65.		0.45	1.	0.22	0.10	0.68	0.24	54.5	49.5	59.8		
MEAN REDESIGN		62396.	55577.	95.		0.49	11.	0.08	0.06	0.55	0.13	57.4	52.7	69.3		

REPS PHASE II KEY DATA BASE PARAMETER: HOTEL/ENVELOPE
ENVELOPE

04-JAN-83
PAGE 2

BUDG NO.	BLDG GLASS AREAS				SKYLIGHT AREA (%ROOF)	GLASS SHADE COEFFICIENT				EXT SHADE	PROCESS LOADS			
	SQ FT	%ENVEL	%SOUTH	%NORTH		SOUTH	NORTH	EAST	WEST		GENERAL KBT/SF	BTUH/SF	SPECIAL KBT/SF	BTUH/SF
56	1168.	16.	6.	6.	0.	0.50	0.50	0.50	0.50	YES	0.000	0.0	0.001	15.5
556	695.	11.	77.	23.	0.	0.50	0.50	0.00	0.00	YES	0.000	0.0	0.000	15.3
71	5430.	14.	21.	37.	15.	0.56	0.56	0.56	0.56	YES	0.000	0.0	0.007	0.0
571	3267.	11.	43.	55.	10.	0.17	0.56	0.56	0.00	YES	0.000	0.0	0.008	0.0
40	2358.	13.	0.	4.	0.	0.00	0.52	0.52	0.52	YES	0.000	0.0	0.000	11.1
540	1441.	15.	27.	18.	2.	0.80	0.85	0.52	0.52	YES	0.000	0.0	0.000	8.8
14	3279.	22.	32.	9.	0.	0.52	1.00	0.52	0.52	YES	0.001	0.0	0.000	0.0
514	2555.	24.	100.	0.	0.	0.57	0.00	0.00	0.00	YES	0.001	0.0	0.000	0.0
107	2157.	9.	37.	30.	0.	0.45	0.45	0.45	0.45	YES	0.000	0.0	0.000	9.6
607	2157.	9.	37.	30.	0.	0.45	0.45	0.45	0.45	YES	0.000	0.0	0.001	9.6
116	6214.	30.	49.	51.	0.	0.42	0.42	0.00	0.00	YES	0.002	0.0	0.003	0.0
616	3072.	17.	0.	100.	0.	0.81	0.81	0.00	0.00	YES	0.002	0.0	0.003	0.0
117	25525.	48.	46.	47.	0.	0.44	0.44	0.44	0.44		0.001	0.0	0.002	11.2
617	15811.	38.	42.	57.	0.	0.44	0.44	0.44	0.00		0.001	0.0	0.002	12.7
<hr/>														
MEAN ORIGINAL DESIGN	6590.	22.	27.	26.	2.	0.48	0.56	0.50	0.50		0.001	0.0	0.002	6.6
MEAN REDESIGN	4143.	18.	47.	40.	2.	0.53	0.60	0.49	0.48		0.001	0.0	0.002	6.6

REPS PHASE II KEY DATA BASE PARAMETER: HOTEL/MOTEL
LIGHTING SYSTEM

04-JAN-83
PAGE 3

P.A. NO.	BIDG NO.	WATTS		ILLUM. LEVEL	LAMP TYPE (PERCENT TOTAL FLOOR AREA)								CONTROL TYPE (% TOTAL FLOOR AREA)							
		PER S.F.			INC	TH	F	NG	NH	HPS	LPS	0	BKR	SW	LV	CPTR	PH	DIM	TC	0
1	56	1.0	21.	98.	0.	2.	0.	0.	0.	0.	0.	0.	3.	97.	0.	0.	0.	0.	0.	0.
	556	1.0	19.	13.	0.	87.	0.	0.	0.	0.	0.	0.	7.	93.	0.	0.	0.	0.	0.	0.
2	71	1.6	12.	70.	0.	8.	0.	0.	0.	0.	0.	22.	16.	70.	0.	0.	0.	14.	0.	0.
	571	1.5	16.	60.	0.	11.	0.	0.	0.	0.	0.	28.	4.	63.	0.	0.	16.	17.	0.	0.
3	40	1.4	15.	65.	0.	35.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	540	0.9	7.	33.	0.	53.	14.	0.	0.	0.	0.	0.	0.	86.	0.	0.	0.	0.	14.	0.
4	14	2.2	28.	69.	0.	31.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	514	1.3	20.	13.	0.	87.	0.	0.	0.	0.	0.	0.	0.	82.	0.	0.	18.	0.	0.	0.
5	107	1.6	50.	94.	0.	4.	0.	0.	0.	0.	0.	0.	0.	95.	0.	0.	0.	5.	0.	0.
	607	0.5	50.	94.	0.	6.	0.	0.	0.	0.	0.	0.	0.	94.	0.	0.	0.	5.	0.	0.
6	116	2.3	26.	95.	0.	5.	0.	0.	0.	0.	0.	0.	3.	97.	0.	0.	0.	0.	0.	0.
	616	2.3	26.	96.	0.	4.	0.	0.	0.	0.	0.	0.	3.	92.	0.	0.	0.	6.	0.	0.
7	117	2.1	18.	77.	0.	23.	0.	0.	0.	0.	0.	0.	22.	67.	0.	0.	0.	11.	0.	0.
	617	0.9	25.	8.	0.	90.	2.	0.	0.	0.	0.	0.	14.	73.	0.	0.	0.	12.	1.	0.
MEAN ORIGINAL DESIGN		1.7	24.	81.	0.	15.	0.	0.	0.	0.	0.	3.	6.	90.	0.	0.	0.	4.	0.	0.
MEAN REDESIGN		1.2	23.	45.	0.	48.	2.	0.	0.	0.	0.	4.	4.	83.	0.	0.	5.	6.	2.	0.

REFS PHASE II KEY DATA BASE PARAMETER: HOTEL/HOTEL
SECONDARY SYSTEM

04-JAN-83
PAGE 4

P.A. NO.	BIDG NO.	SYSTEM ID		T-STAT SET PT.				HEAT TO RA	TEMP CIRL	EXHAUST AIR		SUPPLY		CFM PER RHP	OUTSIDE AIR			ECON TYPE
		INT	PER	COOL	DAY	NIGHT	NIGHT			HEAT RECOVERY	%VENT	%EFF	PER,INT.		%	CFM	CFM/PER	
1	56	0	14	75.	70.	70.	YES	0.	0.	0.	0.	0.86	0.00	1424.	0.	0.	0.	
	556	15	15	80.	55.	70.	YES	0.	0.	0.	0.	0.78	0.86	1499.	0.	0.	0.	
2	71	15	15	75.	70.	70.	YES	3.	0.	0.	0.	1.30	0.69	2415.	10.	14378.	9.	
	571	15	15	78.	70.	70.	YES	8.	0.	0.	0.	1.19	1.82	2782.	6.	7805.	5.	
3	40	0	14	78.	72.	72.	YES	0.	0.	0.	0.	0.75	0.00	849.	28.	6661.	30.	
	540	15	15	78.	70.	70.	YES	8.	0.	0.	0.	0.82	0.75	1151.	12.	4019.	19.	
4	14	3	10	75.	70.	70.	YES	0.	0.	0.	0.	2.29	0.64	4171.	12.	6800.	66.	
	514	0	3	80.	70.	70.	YES	12.	0.	94.	75.	1.02	0.00	1135.	51.	11930.	133.	
5	107	0	14	75.	72.	72.	YES	0.	0.	0.	0.	1.10	0.00	1004.	2.	719.	3.	ENTH
	607	0	5	75.	68.	68.	YES	7.	0.	0.	0.	0.75	0.00	2506.	0.	0.	0.	
6	116	3	14	78.	72.	68.	YES	0.	0.	0.	0.	2.10	1.65	2576.	20.	15703.	79.	
	616	3	14	78.	72.	68.	YES	0.	0.	0.	0.	1.68	1.65	2101.	15.	9377.	47.	
7	117	3	10	75.	72.	72.	YES	0.	0.	0.	0.	1.21	0.58	1055.	14.	23130.	25.	
	617	0	10	75.	72.	72.	YES	0.	0.	33.	75.	0.98	0.00	795.	23.	27890.	30.	
MEAN ORIGINAL DESIGN				76.	71.	71.		3.	0.	0.	0.	1.37	0.89	1928.	12.	9627.	30.	
MEAN REDDESIGN				78.	68.	70.		9.	0.	18.	21.	1.03	1.27	1710.	15.	8717.	33.	

REPS PHASE II KEY DATA BASE PARAMETER: HOTEL/HOTEL
PRIMARY SYSTEM

06-JAN-83
PAGE 5

P.A. NO.	BLDG. NO.	CHILLER COOLING CAP	HEATING KTF.	HEAT RECOVERY	HEAT PUMP TYPE	HP HEATING COP	COOLING FUEL TYPE	HOT WATER STORAGE (BTU/BTU CAP)	AUX. KW COOLING VAR.	CONST	AUX. KW HEATING VAR.	CONST	S.F. PER TON	HEATING BTU PER SF
1	56 556	1.8 2.3	1.0 1.0			0.0 0.0	E E	0. 0.	0. 6.	0. 0.	0. 0.	0. 0.	368. 392.	14. 3.
2	71 571	2.6 0.3	1.0 1.0		11 11	2.9 2.9	E E	3. 1.	5. 5.	70. 60.	0. 0.	0. 0.	0. 0.	2. 9.
3	40 540	1.8 2.5	1.0 1.0		11	0.0 2.5	E E	0. 0.	0. 13.	0. 0.	0. 0.	0. 0.	452. 0.	25. 0.
4	14 514	0.7 0.9	1.0 0.8			0.0 0.0	I I	0. 0.	10. 0.	0. 5.	9. 0.	0. 2.	275. 527.	64. 19.
5	107 607	2.0 2.3	1.0 0.8			0.0 0.0	E E	0. 0.	0. 0.	0. 6.	0. 0.	0. 3.	410. 601.	32. 9.
6	116 616	2.9 1.8	1.0 1.0			0.0 0.0	E E	0. 0.	0. 1.	0. 0.	0. 0.	0. 0.	296. 291.	37. 12.
7	117 617	3.9 4.7	1.0 1.0	YES		0.0 0.0	E E	0. 0.	17. 0.	15. 46.	0. 0.	0. 0.	324. 387.	29. 16.
MEAN ORIGINAL DESIGN		2.2	1.0	0		0.4		3.	7.	12.	1.	0.	354.	28.
MEAN REDESIGN		2.1	0.9	1		0.8		0.	4.	17.	0.	1.	440.	10.

SUMMARY OF SECTION CONTENTS

- 4. Clinics and Hospitals
 - a. Article: "Energy to Recover"
 - b. Building Type Analysis
 - 4.1 Health Design Criteria
 - 4.1.1 Lighting Requirements
 - 4.1.2 HVAC Requirements
 - 4.2 Redesign Strategies
 - 4.2.1 Patient Areas
 - 4.2.2 Support Areas
 - 4.2.3 Ancillary Functions
 - 4.2.4 HVAC Zoning
 - 4.2.5 Plant and Heat Recovery
 - c. Key Energy Parameters - Graphic Presentations
 - d. Key Energy Parameters - Extractions from Computer Stored Data

CHAPTER 10: THE HISTORY OF THE UNITED STATES

- a. Colonial and Revolutionary War
- b. Antebellum Period
- c. Civil War and Reconstruction
- d. Gilded Age and Progressive Era
- e. World War I and the Roaring Twenties
- f. The Great Depression and World War II
- g. Post-World War II Era
- h. The Cold War and the Vietnam War
- i. The 1960s and the Civil Rights Movement
- j. The 1970s and the Watergate Scandal
- k. The 1980s and the Reagan Revolution
- l. The 1990s and the Clinton Presidency
- m. The 2000s and the Bush Presidency
- n. The 2010s and the Obama Presidency
- o. The 2020s and the Biden Presidency

Energy to recover

The energy redesign of hospitals is the subject of the sixth article in this energy-conscious design series. Although the demanding environmental requirements of hospitals limit the use of conservation strategies that are viable in other building types, the researchers find that HVAC and heat recovery strategies were keys in dramatically reducing energy use without compromising health care criteria.

Apart from restaurants, hospitals are by far the most energy intensive of all the building types studied in this research effort (see Fig. 2 and P/A, April 1982), approaching a mean annual energy consumption of 240 kBtu per sq ft in the original designs. While areas as diverse as surgical suites and patient rooms have different operating hours, internal loads, and use profiles, the predominant 24-hour-a-day operation of hospitals is inherently energy intensive. Strict environmental, life safety, and regulatory requirements heavily affect design requirements for hospital HVAC systems because precise temperature and humidity levels and high ventilation rates are maintained. While this is costly from an energy standpoint, it is necessary; the environmental requirements for a burn victim or a cardiac patient can be nearly as critical to their recovery as drugs and medical treatment.

The research in this article is based upon results from the redesign samples of two major types of health care buildings: clinics and hospitals. The ten clinics resemble office buildings more than hospitals, as their predominant space use is for offices and circulation. Medical service areas are minimal. They lack patient rooms and the related housekeeping and support areas that accompany them. Because the clinics were similar to office buildings, we will treat them separately (see sidebar) and feature the hospital redesign effort.

The eleven hospitals contain the full range of ancillary, support, and patient areas among the three primary care facilities, five regional community hospitals, a mental health care community hospital, a mental health building complex, and a cancer research facility.

Overall, a 40 percent energy saving was achieved by the hospital redesign teams, resulting in an estimated mean annual energy performance of 140 kBtu per sq ft per year. The largest savings were in heating energy and related auxiliary equipment such as fans and

pumps. In many instances this energy use was cut in half. Additional energy savings of about 21 percent were found in lighting systems.

The widespread perception that hospitals are internal-load-dominated is questioned by certain aspects of the energy results. The design energy data (Fig. 2) show that the predominant energy consumption is for heating, taking seasonal heating and cooling equipment efficiencies into account; this is not the intuitive finding. Heating energy consumption would generally not be that high in buildings that are internally loaded. However, major portions of hospitals have substantial heating needs. Patient areas, corridors, and certain support areas that do not experience high internal loads are often ventilated continuously. Another cause of high heating energy is humidity control of ventilation air in areas that require narrow temperature and humidity ranges.

The problem of analyzing energy use in these hospitals is further complicated, as "process" energy loads were not modeled in the computer energy analyses (see P/A, April 1982). The lack of this process energy in conditioned spaces could have caused heating energy to be erroneously exaggerated. Unfortunately, there are not adequate redesign data to answer these process load questions for this complex building type. Extensive statistical analysis that tried to relate weather data to the hospital sample's energy use uncovered no significant cause and effect relationship. Indeed the BEPS energy targets for hospitals are a uniform 140 kBtu per sq ft per year nationwide.

Hospital redesign strategies

Our analysis of the hospital redesigns examined the strategies for both individual functional spaces and the whole building. As shown in Fig. 1, conservation opportunities and design strategies vary by function. The three major functional groupings of hospital spaces used in our analysis include: 1 patient areas, 2 ancillary facilities such as operating rooms, intensive care units (ICUs), emergency rooms and their direct support areas, which have the most strict

environmental requirements, and 3 support service areas, including offices, pharmacies, treatment rooms, food service, storage, and other space types.

The substantial energy reductions achieved by the hospital redesign teams were accomplished in a redesign process that had more constraints than in other building types. Not only did they need to meet all the normal regulatory requirements for hospitals, but they also had to adhere to the clients' original building program and health care policies. Even though the emphasis of the experiment was on performing an energy redesign, this was of secondary importance to the primary responsibility for designing to health care requirements. A survey of both original and redesign specifications for environmental conditions, outside air, and lighting levels confirms that critical health requirements were not compromised because of energy conservation.

The redesign teams attempted to use energy efficiency measures at the functional space level where appropriate, chiefly in patient and support areas. In the ancillary spaces no modifications to lighting levels or environmental setpoints were found.

Patient rooms: Redesign strategies in patient rooms emphasized control of conduction gains and losses. These loads require attention because of constant space temperature setpoints and the inappropriateness of night temperature setbacks. Patient room wall U-values were generally improved. Glass area in exterior patient rooms was reduced, and insulating glass was added when not present in the original design. Other window strategies included solar shading and insulating drapery.

Opposite: The redesign strategy matrix for this 130-bed community hospital illustrates the applicability of opportunities and constraints found in the hospital sample. Lighting strategies, for example, were used only in support areas. Patient rooms face northeast and northwest to minimize solar gain. Stair towers and elevator shafts serve as buffers on the south, and the ancillary wing is largely windowless except for north-facing monitors. Noncritical support areas on its upper floor receive natural lighting, while critical areas are located on the ground floor. Strategic HVAC zoning uses multiple VAV systems, enthalpy economizers, and occupancy-based controls. Humidity control is restricted to critical areas. The patient tower is zoned by exposure. Surgery and emergency areas have the option of operating as a constant volume system when in use. The ICU and other critical areas retained the original constant volume system, reheat coils, and 100 percent outside air. Heat recovery chillers are used to preheat service hot water. Separate boilers are provided for heating and sterilization. Frank L. Hope & Associates, Architects and Engineers.

The clinic redesigns

The redesign sample of eleven clinics ranges in size from 6000 to 93,000 sq ft. With the exception of a few specialty clinics, these buildings are essentially offices with limited medical areas. Their operating profiles resemble those of office buildings (see P/A, June 1982) except that they are occupied on weekends and evenings. This is one reason why their original mean energy use of 86 kBtu per sq ft per year is higher than office buildings. In the redesign, clinic energy use was reduced by 48 percent to 51 kBtu per sq ft per year.

Like office buildings, clinics share the problem of diurnal heating and cooling. Daytime operation finds these buildings subject to internal gains and solar loads that often require cooling. During unoccupied periods they experience significant conductive heat loss. It is not surprising, therefore, to find that the clinic redesign teams used many of the strategies found in the office sample. To optimize gains and losses, the clinic redesigners improved the composite U-value and tended to use more compact building forms. The selective reorientation of glass by exposure depending on climate was also reminiscent of the office redesigns. Glazing areas were generally reduced and solar shading devices employed. Several of the clinics also used insulating shutters as an additional window treatment.

Lighting strategies, such as using fluorescent fixtures with energy-efficient ballasts in place of incandescent lighting, were used. However, daylighting was not predominant in the clinics and only three designs using skylights and photocell controls were noted.

Nearly all the original clinics used constant volume or dual duct HVAC systems. However, six of the clinic redesign teams chose VAV systems, while three selected heat pumps. Other similarities to office HVAC strategies include the widespread use of economizer cycles, changes in heating and cooling setpoints, the use of night setback strategies, and reduction of outside air quantities. In contrast to the hospitals, the one instance of using a heat wheel constitutes the only clinic heat recovery application.

We did not find strategies that relied on unique characteristics of clinics in the inventory of clinic redesign strategies. From a design standpoint, therefore, it may be more appropriate to view them as offices.

Original patient room lighting levels, installed capacity, and fixture types were retained in the redesign, apparently because of adherence to design criteria. Patient room lighting systems must serve multiple needs, such as providing good color rendition for patient examination and diagnosis, as well as the patient's own needs, such as reading without disturbing others.

Support areas: Reduction of controlled lighting capacity was observed in patient support areas such as corridors and nurses' stations, as was the use of improved lighting controls, such as timeclocks and local two-step switching. Two hospitals used photocell-controlled daylighting strategies for nurses' stations and corridor lighting.

Lighting and environmental criteria can be relaxed in certain areas without detrimental effects on health care. Lighting levels and installed capacity were reduced in storage areas, mechanical rooms, corridors, and similar spaces. Incandescent lighting was generally replaced with fluorescent fixtures using high efficiency ballasts. Photocells, local two-step switching, and timeclocks were frequently used. In office and administrative areas, VAV systems were employed, and task lighting was used where applicable.

In hospital kitchens, a prevalent strategy was the use of heat recovery coils in kitchen exhaust ducts, adding another resource to plant heat recovery and storage systems. In several instances mechanical and storage areas were relocated to an advantageous exposure to serve as buffer zones for conditioned interior space.

Building form and envelope

Basic decisions on the organization, placement, and treatment of patient rooms seems to have governed most of the buildings' form and orientation in the redesigns.

In a hospital, patient rooms can comprise up to 75 percent of a hospital's exterior surface areas, and as is characteristic of most "sleeping rooms," conductive heat loss and gain are of concern as is solar control. In half of the redesigns, patient rooms with exterior exposure were minimized by locating them around interior courtyards and enclosed atriums in locations as diverse as Chicago and Dallas. Not only did this strategy allow the form to become more compact, reducing exposed surface area for these external-load-dominated spaces, but it also allowed natural light to reach patient rooms.

FIGURE 2: ANNUAL ENERGY END USES FOR REDESIGN EFFORTS

For the exterior patient rooms, the redesign teams increased the overall thermal integrity of the envelope. This was accompanied by a variety of fixed and movable interior and exterior shading devices to control solar gains on a seasonal basis. Several redesign teams reported reductions of peak heating and cooling loads by as much as one-half through the combination of these strategies.

It is important to point out that passive solar heating strategies were not used in patient rooms because of the need to maintain stringent environmental conditions for patient care. Although seasonal control of solar gain was used, no provisions for thermal mass storage were made.

Although these patient room treatments often led to noticeably different forms, no major changes in patient, ancillary, and support area relationships were noted.

HVAC zoning strategies

Unlike other building types previously analyzed in this series, the hospital redesigns did not exhibit any trends to adopt a particular type of HVAC system. What is apparent in the redesigns is a strategic

regrouping of the mix of functional spaces assigned to a particular type of HVAC system on the basis of similarities in operational hours, temperature setpoints, and humidification requirements. Many of the redesigned HVAC systems were arranged to provide humidity control through reheat at the space level rather than at the central air handler. This also allowed more flexible control of ventilation air.

It is likely that the significant heating and cooling energy reduction in the redesigns was achieved in part with this strategy of HVAC zoning, as unnecessary system operation and energy required for precision conditioning of supply and ventilation air was minimized.

Plant strategies: The predominance of heat recovery and thermal storage strategies in all the hospital redesigns is not surprising, as a near ideal environment for these applications exists. Recoverable waste heat resources are co-

incident in time with many energy demands, and multiple resources can be tied into recovery systems. Resources such as refrigeration, central water chilling equipment, and large quantities of exhaust air are often available continuously. Combined with thermal storage systems and the central control available at the plant level, the heat recovery sources can be matched with energy needs such as heating and preheating of service hot water and ventilation air. In some instances recovered energy was sent to reheat coils for humidity control or to heating coils in dual duct systems.

Double bundle (heat recovery) chillers were used in most hospital redesigns, primarily to help meet hot water loads. Two hospitals used chilled water coils to remove heat from exhaust air. In a 96-bed mental health facility (#15) this was reported to reduce electricity demand for make-up air heating by two-thirds. Although extra chiller electricity is used in this strategy, a community hospital (#18) in Texas estimated that six Btu's were reclaimed for each Btu expended in the recovery process. Other heat recovery applications included heat wheels, "run-around" loops, variable chilled water pumping, evap-

orative humidifiers, and the use of separate steam boilers for sterilization processes. Calculations by several of the hospital redesigners placed the conservation potential for heat recovery at two to three times that of architectural or lighting strategies.

Observations and conclusions

The hospital redesign experience is distinguished from that of the other building types in that the major redesign emphasis was placed on HVAC systems and heat recovery. The choice of architectural strategies (especially those for patient rooms) heavily influenced the buildings' form and reduced peak heating and cooling loads, but was not the source of the predominant redesign energy savings.

The greatest value of the hospital redesigns, however, may be the demonstration that energy-efficient design is possible even under the most constrained circumstances. Although hospital conservation potential was frequently limited at the space level, the redesign teams were able to achieve substantial energy savings without compromise of health care requirements. □

Contributors: A number of individuals and organizations have contributed to the development of this article. Principal researchers: Harry Misuriello, Principal, W.S. Fleming & Associates; Joseph J. Deringer, President, and Santiago Moreno, Associate, Gilford, Deringer and Company.

Researchers: James Binkley, Chief, and Ted Kurkowski, Program Manager, Commercial Building Systems Analysis, Architectural and Engineering Systems Branch, DOE; John Stoops, Project Manager, Ray Reilly, Program Manager, and Stan Pansky, Project Architect, Battelle Pacific Northwest Laboratories; John H. Cable, Principal, The Ehrenkrantz Group; Roger Easley, Consultant to Battelle; Terry Ann Nyberg with Gilford, Deringer and Company.

This effort has been funded by Battelle Northwest Laboratories under a program sponsored by the Buildings Division of the U.S. Department of Energy. For a complete description of this article series, see P/A, April 1982, p. 110.

b. Building Type Analysis: Clinics and Hospitals

The objective of this section is to supplement the information contained in the Clinics and Hospital article ("Energy to Recover", Progressive Architecture Magazine, February, 1983) by providing additional detail on both the life safety requirements of clinics and hospitals and the most effective strategies that apply to these building types. Without some background on the strict environmental, life safety and regulatory requirements of health care facilities, it is difficult to understand the limits and opportunities placed on the redesign process. A more extensive discussion of energy targets and opportunities and redesign schemes found in these building types are contained in the article.

4.1 Health Design Criteria

The following material includes design considerations accepted in lighting and HVAC design practice in hospitals, and illustrates the application of such design strategies on the redesigns. More detailed design considerations and requirements can be found in the two sources primarily used in the data analysis for the article: ASHRAE Handbook, 1981 Systems; and the IES Lighting Handbook.

4.1.1 Lighting Requirements. The following section describes lighting requirements for various spaces within health facilities.

Patient Rooms. The design problem in patient rooms is to reconcile the lighting requirements for various individuals in different roles; i.e., patient, nurse, doctor, housekeeper. Lighting should be planned to be adequate for all types of users over the full range of ages at any time. Indeed, multiple lighting systems are frequently found in hospital rooms.

The minimal requirements of the Construction and Health and Resources Administration require the provision of daylighting to enable each patient to be cognizant of the outdoor environment. Some type of surgical task light must be available for emergencies and adequate illumination is required for the reading of devices

monitoring the various activities in which the patient may be engaged.

Ancillary Areas. The operating room is the most important lighting task in the hospital. Lighting criteria includes eliminating shadows and providing excellent color rendition for tissues, organs and blood. Heat from surgical lighting must be minimized for the physician's comfort and also because body tissues exposed during an operation must not be excessively heated or dried. Lighting levels must be uniform to enable surgeons to glance to and from their work without having to take time for their eyes to adjust to large differences of luminance. Fluorescent luminaires must be designed to reduce electromagnetic interference to electronic equipment in a life support system.

Support Areas. In nurses stations lighting is often in continuous use night and day. Transition lighting is required as nurses make frequent trips from station to patient facilities. For routine nursing, soft light is required for patient's comfort, variable control dimmers are suggested.

In pediatric lighting, the use of daylight is essential. There should be a light and sunny atmosphere. In nurseries, general lighting is required for observation of infants; however, retinal over-exposure must be avoided.

4.1.2 HVAC Requirements. The role of air conditioning systems in hospitals goes beyond maintaining comfort. Most often, environmental conditions are a factor in patient therapy and in some instances become the major treatment. For instance, hot, dry environments may be used to treat patients with certain types of arthritis, while hot wet environments are needed to treat severe burn victims. A cool, dry environment favors heat loss by radiation and evaporation from the skin which is required for some treatments, such as cardiac patients.

Hospital HVAC systems are different from other building types because there is a need to restrict air movement into and among the various departments. Specific ventilation rates are also necessary to dilute and remove contamination due to odors and airborne micro-organisms. In addition, temperature and humidity requirements change according to the area considered.

Air quality is maintained by elaborate filtration systems. Such filters can increase static pressure and fan energy consumption.

Ultraviolet sterilizing lamps, both in the space and in the duct, have been considered. However, highly controlled maintenance is required and may be more complicated than conventional filter installations. Contamination control is often accomplished by positive or negative pressure on spaces. Generally, highly contaminated areas should maintain a negative pressure relative to those rooms adjoining them. Operating rooms require positive pressurization to insure that air within the space is free of contamination.

There are a number of factors which influence the zoning of air handling systems in hospitals. These are:

- o Compensation for exposures by orientation
- o Desire to separate air systems for different hospital departments
- o Flexibility of operation
- o Simplify provisions for operation of emergency power

It is desirable to separate exhaust systems by department, especially for surgical, obstetrical and pathology departments. Care should be taken to interlock surgical exhaust and supply air fans to maintain relative air balances. Standby capacity must be designed into air handling systems in case power is interrupted. This is done by manifolding the air supply from several air handling units.

Following are some of the factors that should be taken into consideration for all the major functions of a hospital when designing a HVAC system. As pointed out in the article, energy conservation necessarily has diminished importance in the face of these requirements. However, major energy savings were achieved by the redesign teams which indicate that substantial improvements are possible.

Administrative Departments. Includes main lobby, admitting, business offices and medical records. No unusual requirements. Separate air handling systems are recommended.

Diagnostic and Treatment Facilities. Includes laboratory, pathology, radiology, physical therapy, occupational therapy and inhalation therapy. Examples of some same use requirements include:

Laboratories. Comfort and safety are important design criteria. There are chemical fumes and odors, vapors and heat from equipment. Heat gain can come from many sources, and can constitute the major portion of the cooling load. Exhaust of radioactive or infectious materials requires also high efficiency filters.

Generally, labs should be under a slight negative pressure.

Bacteriology Units. Air velocity should be minimal. A sterile environment is required.

Infectious Disease Labs. Requires six (6) ACH and should have negative pressure. Exhaust air requires sterilization. This is often done with electric or gas fired heaters in this exhaust duct.

Physical Therapy Department. Has internal loads from electro-therapy equipment. Hydro-therapy equipment maintains water at 80°F and can cause latent heat loads.

Inhalation Therapy Department. Requires extremely clean air and should have a positive air pressure.

Nursery. Requires narrow and constant temperature and humidity conditions for newborns and air flow patterns to minimize drafts.

Nursing Department. Patient rooms require two air changes per hour of outside air; re:circulation is permitted. Separate codes apply to ventilation of toilets, bedpan closets, bathrooms and interior rooms.

Isolation Unit. Other patients need to be protected from the patient's disease in the isolation room and the patient needs to be protected from contamination from the rest of the hospital. Sometimes an anti-room serves as an airlock. Exhaust air should be filtered and discharged directly outdoors.

Surgical Department. Most contamination in the operating room comes from the surgical team which is in the vicinity of the operating table. Air flow should remove contamination from around the operating table towards the outside of the room. The typical operation of operating rooms is twelve hours a day.

HVAC system design should allow for individual operating room control for energy conservation. Separate air exhaust system is required for removal of anesthetic trace gases which are flammable. Positive air pressure is required within the operating room relative to adjoining rooms.

Emergency Department. This is the most highly contaminated area in the hospital. Patients arrive in

a soiled condition with relatively large numbers of persons accompanying them. Trauma rooms in the emergency department need twelve (12) air changes per hour and re-circulation is not permitted. Temperature and humidity requirements are the same as the operating rooms. Waiting rooms need ten (10) air changes per hour with negative air pressure.

Summary. The foregoing material highlights the stringent and diverse environmental requirements with which the designer must contend. It is apparent that ventilation requirements are high in nearly every hospital department, and comfortable temperature ranges must be maintained. The following section describes the redesign strategies used to accomodate health care criteria and energy conservation.

4.2 Redesign Strategies

The following is a review of hospital redesign strategies which were applied according to space type. However, there are a number of strategies that cut across the entire building. This would include:

- o siting;
- o daylighting in corridors common to all areas of a hospital;
- o zoning (or re-zoning) of HVAC systems;
- o heat recovery strategies.

The major space types analyzed are: patient areas; medical and non-medical support areas; and ancillary functions. Major strategy types covered are HVAC zoning and plant/heat recovery.

4.2.1 Patient Areas. Patient rooms often comprise only between 10% and 25% of a hospital's floor area. Federal Codes require the location of patient rooms so that they receive natural lighting. Their usual exterior location subjects them to conductive heat gain and loss, as well as to solar gain. While patient rooms may be perceived as externally load dominated (and may well be due to ventilation air requirements), they can also be subject to significant internal loads from medical equipment and instrumentation, as well as a variety of lighting systems and televisions that may be in operation twelve (12) hours a day or longer.

Many of the redesign descriptions specifically note that patient rooms were given southern exposure for passive solar heating assistance as well as for daylighting. Probably many of the form

changes in the redesign resulted from this strategy. These were accompanied by solar control strategies to minimize cooling loads. Form changes encompassed mostly atria and open courts.

In hospitals, atria can fulfill two functions:

- 1) As an unconditioned buffer zone serving as an air plenum, i.e., the return air path is directed into the atrium. The main benefit of atriums is to limit conduction losses from adjacent functions. Also, these spaces are not generally for circulation. Two hospitals used these strategies for patient rooms (#13 Kansas, #12 Chicago). However, such a strategy represents a deviation of the National Fire Protection Association (NFPA) 101 Life Safety Code, although it helps configure the building into a more compact form.
- 2) As a south-oriented space, used for circulation, with either remote or direct thermal storage. However, only one (1) redesign case (#19 Arlington, TX.) used a non-conditioned central atrium with direct rock thermal storage.

Open courts were most often resulted from compacting the building form. In building #15, Louisville, KY, patient rooms were placed on the exterior perimeter of the court, while other support functions were placed on the court's interior perimeter. Note in this case that patient rooms would also be shading support areas limiting their solar gains.

4.2.2 Support Areas. This appears to be one of the largest space use categories in hospitals, and is one area where lighting reduction and switching from incandescent to fluorescent lighting have the most potential. This area also includes kitchen and food service facilities where heat recovery saw many applications.

As an example, kitchen recovery was used on exhaust hoods in one hospital redesigned with estimated savings of 1.3×10^7 BTU's per year. For the same building sunscreens were estimated to save 2.5×10^7 BTU's per year on the Heating load. This illustrates the relative magnitude of energy conservation potential between envelope strategies vs. heat recovery strategies.

4.2.3 Ancillary Functions. Ancillary strategies are discussed in the context of the overall HVAC system and plant configuration. However, some specific ancillary strategies found in the redesigns include: Reducing air volumes in ancillary spaces during non-use hours; and, filtering systems re-evaluating so that static pressures could be minimized.

4.2.4 HVAC Zoning. Re-zoning HVAC systems on the basis of similar operating hours is effective for controlling and scheduling their use. Typical hours per day of system operation for various hospital space types are shown below:

- o 24 hour - ICU, patient rooms and emergency rooms
- o 15 hour - dining areas
- o 10 hour - clinic/pharmacy
- o 8 to 24 hour - operating rooms and sterilization facilities
- o 8 hour - office, data processing, accounting and central sterile supply
- o 0 hour - mechanical rooms

4.2.5 Plant and Heat Recovery. Plant equipment and heat recovery are, in the end, the most effective strategies. In a diverse building, such as a hospital, it is the one area where some central control can be imposed. Also, it is the place where waste heat can be reclaimed, stored and re-routed to the fluctuating building loads such as preheating and reheating of air, and preheating service hot water.

Heat reclaimed from a double bundle condenser was used in one hospital redesign to provide preheat and heating coil energy to the dual duct system such as heat recovery application mitigates the inherent high energy use of this system type, while taking advantage of its excellent temperature control capabilities. In another hospital, exhaust air heat recovery was estimated to reduce electric heating for ventilation air from 16,537 BTU's to 5,209 BTU's per square foot per year by using a chiller to cool off the exhaust air as it left the building. This hospital further heated its domestic water with chiller heat recovery.

In general, the hospital redesigns achieved their significant energy savings through:

- o Strategies geared towards minimizing heat gain/loss in patient rooms
- o Efficient zoning of HVAC systems.
- o Heat recovery

The common theme between these strategies is that they are "hidden" from patients and staff. The design allows environmental conditions to be maintained, while using much less energy than would be otherwise.

FIGURE 4.1. Hospitals and Clinics

FIGURE 4.2. Frequency of Strategies - Hospitals and Clinics

FIGURE 4.3. Conduction - Hospitals and Clinics

FIGURE 4.4. Solar Control - Hospitals and Clinics

FIGURE 4.5. Lighting - Hospitals and Clinics

FIGURE 4.6. Primary and Secondary Systems - Hospitals and Clinics

FIGURE 4.7. HVAC Set Points - Hospitals and Clinics

FIGURE 4.8. Equipment Efficiency - Hospitals and Clinics

FIGURE 4.9 A&B. Miscellaneous Energy Parameters

FIGURE 4.9 C. Miscellaneous Energy Parameters

FIGURE 4.10. Space Use & Cost Change - Hospitals and Clinics

Figure 1. Comparison of the results of the two methods.

Figure 2. Comparison of the results of the two methods.

Figure 2. Comparison of the results of the two methods.

Energy: A class by itself

The intermittent usage patterns inherent in elementary and secondary schools resulted in redesign decisions that often increased natural lighting while minimizing conductive gains and losses. Mechanical system controls for idle spaces were also important contributors to a higher than average redesign energy saving.

Contributors: A number of individuals and organizations have contributed to the development of this article. Principal researchers: Joseph J. Deringer, President and Santiago Moreno, Associate, Gilford, Deringer and Company; Harry P. Misuriello, Principal, W.S. Fleming & Associates.

Researchers: James Binkley, Chief, and Ted Kurkouski, Program Manager, Commercial Building Systems Analysis, Architectural and Engineering Systems Branch, DOE; John Stoops, Project Manager, and Ray Reilly, Program Manager, Battelle/Pacific Northwest Laboratories; John H. Cable, Principal, The Ehrenkrantz Group; Roger Easley, Consultant to Battelle; Terry Ann Nyberg, Gilford, Deringer and Company; Verna D. Hawkins, with W.S. Fleming & Associates.

This effort has been funded by Battelle Pacific Northwest Laboratories under a program sponsored by the Buildings Division of the U.S. Department of Energy. For a complete description of this series, see P/A, April 1982, p. 110.

In thousands of school buildings, energy conservation retrofits have been financed through the Federal "Schools and Hospitals" Program with funds appropriated by Congress and administered by state governments according to Department of Energy (DOE) regulations. Unfortunately, this (or similar) aid is not available to improve the energy efficiency of new schools in the design stage. The redesign samples of 11 elementary and 11 secondary schools discussed in this article provide examples of how the energy aspects of conventional school construction could be improved.

The intermittent and irregular usage patterns in many school spaces have a significant influence on the selection of energy design strategies. On a daily basis, areas such as gymnasiums, auditoriums, and to some extent, classrooms are not scheduled for continuous occupancy. Often, however, the energy systems serving these spaces are designed or controlled to operate as if they were. Internal loads are influenced by the type of activity within the space as well as by occupancy density, lighting, and equipment usage. When cafeterias are used for social activities—dances, for example—higher sensible and latent loads than those experienced during normal lunch periods are placed on HVAC systems. Schools are often used in summer and at night for adult education or civic affairs. Thus HVAC systems and building design strategies must handle both large and small loads efficiently during variable time periods.

Theoretically, schools should operate between 1400 and 1500 hours per year, including seasonal and summer vacations. Actual school operation can result in closer to 2500 to 3500 hours per year. A major factor in the difference in energy intensity between primary and secondary school types is the longer

hours of operation shown for the latter in Fig. 1. The mean original energy consumption for secondary schools was 85 kBtu per square foot per year, significantly higher than that of 58 kBtu per square foot per year found in the elementary schools. In the energy analysis, these operating profiles were used each week of the year and did not account for traditional seasonal and summer vacations. However, significant usage for other activities may have caused the energy estimates shown in Fig. 2 to be only slightly overstated.

Other design requirements influence energy use. All types of schools require large quantities of conditioned ventilation air. In many school spaces, design occupancy densities of 50 to 75 people per thousand square feet are typical. Ventilation rates are higher than in other building types, often in the range of 10 to 15 cubic feet of air per minute per person. Infiltration can also be a constant source of outside air due to frequent door openings and normal building cracks. In fact, the inrush of hot outside air at the precise time when school lets out has been found to be the cause of peak electric cooling demand in some schools.

The high internal loads experienced in many school spaces such as classrooms, often result in only minimal heating during occupied periods. Therefore, on an annual basis, most heating energy will be used to maintain space temperatures when these areas are vacant. Depending on climate, design strategies that control conduction during intermittent and extended unoccupied periods can be effective.

After HVAC, lighting is the largest energy end use in schools. Because learning spaces can contain various visual tasks, lighting levels are often selected on a "worst case" basis. In many instances, certain school spaces, such as work shops and auditoriums, require multiple lighting systems. The long hours of school building usage also contribute to large artificial lighting energy consumption.

Other major energy users in schools include kitchens, cafeterias, and service hot water for showers. The "process" energy for cooking was not treated in

CROSS SECTION

LONGITUDINAL SECTION

SECONDARY SCHOOL REDESIGN
(DETROIT MI)

ELEMENTARY SCHOOL REDESIGN
(SAN DIEGO CA)

(Left) Surface-to-volume ratio is reduced by a compact pyramid form. Berming is used to aid in control of conduction losses. Relocated to the upper floor, classrooms take advantage of direct gain passive heating and daylighting using skylights in conjunction with extensive lighting controls. Solar gain through south-facing clerestories is controlled by exterior shading. Filling air spaces in the double-glazed north-facing clerestories at night with expanded polystyrene pellets minimizes thermal conduction. (Below) Diffuse natural lighting enters classrooms and corridors with minimal heat gain via six-foot-high north-facing clerestories. Antiglare louvers on these clerestories double as security grilles. Prevailing winds provide natural cooling through west-facing wind scoops on the roof and wall-mounted wind inlet louvers on the first and second floors. The redesign required no mechanical cooling system.

FIGURE 1: SCHOOL REDESIGN EXAMPLES

Energy-conscious design: Schools

the redesign experiment; the kitchen ventilation and hot water requirements were.

Redesign strategies

The school redesigns range in size from 11,000 to 276,000 square feet and include neighborhood schools, regional high schools, vocational schools, a business college, and a law school. With the exception of the five-story law school, all buildings are one and two stories in height.

The redesign strategies concentrated on the control of conduction during unoccupied periods, the reduction of artificial lighting energy, and minimizing the conditioning of ventilation air. With these strategies, the elementary and secondary school redesign teams reduced mean design energy consumption by 47 percent and 40 percent respectively.

In the majority of instances, the combination of site, form, envelope, and daylighting strategies led to a markedly different concept for the buildings' form and space organization. Two representative redesign examples are shown in Fig. 1.

Control of heating and cooling loads: Since much of a school's annual heating energy requirements in cold climates are for its considerable unoccupied periods, conduction losses were minimized wherever possible. This particular energy design problem appears to have been considered in many of the original buildings. Original designs located in these climates were already well insulated and major improvements in wall U-values were observed only in the warmer locations. Glass U-values were improved in nearly every instance (see Fig. 4) by upgrading from single to double glazing. In almost all the schools, however, glass area in both the original design and the redesign was generally minimal. In half the buildings, glass area was less than five percent of gross floor area, and in the remainder, all but four were ten percent or less. Protection from vandalism, rather than energy efficiency may have been the major motivation for this.

Berming: The most striking architectural feature in the redesigns was the use of earth berming. As shown in Fig. 4, 15 of the 22 school redesigns increased the percentage of walls below grade in an effort to reduce conduction gains and losses in all climates. In some of the extreme examples, more than 60 percent of the building's wall area was placed below grade. The effectiveness of berming is difficult to assess accurately. The thermal behavior of walls below grade has only begun to be well understood, and is influenced by local soil conditions such as composition and

KBTU/SQ. FT. YR

FIGURE 2: ANNUAL ENERGY END USES FOR THE REDESIGN EFFORT

FIGURE 3: PERCENT CONSTRUCTION COST CHANGE FROM ORIGINAL TO REDESIGN

GLASS U-VALUE

FIGURE 4: ENERGY DESIGN PARAMETER VARIATIONS FOR ALL SCHOOLS

average moisture content. This strategy has the advantage, however, of minimizing the temperature difference between the conditioned space and the exterior wall because of the relatively stable earth temperature below the frost line. Berming did force a change in wall construction, depending on the amount of wall below grade, but there is no evident relationship between overall building cost increases and the use of this strategy (see Fig. 3). For example, in buildings #1, #12, and #22, where the most ambitious berming was observed, the cost data are inconclusive. Where vandalism is of concern, the use of extensive berming can have obvious utility beyond the control of thermal conduction.

When not placed on the roof for natural lighting (discussed later), glazing was located to the south in cold climates and to the north in the warmer climates in these bermed buildings.

Where southern exposure was given to windows, massive masonry walls and direct gain passive solar systems were often employed to further offset unoccupied heating loads by taking advantage of thermal time lags. Glass relocation was often accompanied by solar control measures such as fins, overhangs, and interior shading devices.

Other conduction control strategies included the use of nonconditioned spaces such as mechanical rooms as buffer zones on the building's perimeter and form compaction. As discussed later, use of exterior buffers often depended on the basic floor plan chosen to implement various daylighting strategies. Compacting the building form to reduce nighttime heat loss was a strategy used in more than one-third of the redesigns, primarily those located in cold climates.

Lighting

In both the elementary and secondary schools, artificial lighting accounted for approximately 20 percent of annual energy use. The substantial lighting energy reductions (see Fig. 2) can be attributed to a reevaluation and sub-

sequent reduction of lighting levels, primarily in classroom spaces. As a result, installed lighting capacity was reduced to approximately 1.5 watts per square foot (see Fig. 4) by simple elimination of fluorescent fixtures.

Natural lighting: In the school redesigns, examples of nearly all approaches to daylighting were found, including clerestories (oriented to either the north or south), monitors, skylights, sunscoops, and windows. Strong relationships between internal spatial reorganization and choice of basic daylighting approach were observed. Of course, the use of daylighting is only one functional criterion in determination of the plan. Designers employing side daylighting for classrooms located on the building's perimeter could use interior circulation to enclose an administration and service core. Those using clerestories, monitors, and skylights often used the building's perimeter to locate buffer zones and placed classrooms on the building's interior.

To accommodate space usage variation, daylighting strategies were accompanied in most instances with multiple switching schemes and photocell controls, which sometimes provided several levels of artificial lighting reduction. Thermal shutters were not used, because of the perceived poor payback at the time of the experiment. The trade-offs between artificial lighting savings and possible increases in conduction or solar gain should always be assessed. Although the energy analysis computer model was unable to estimate the energy reductions due to daylighting, the solar gains and conductive losses through daylighting apertures were accounted for in the buildings' thermal analysis. The energy results indicate that neither heating nor cooling energy increased due to this strategy.

HVAC strategies

The school redesigns experienced little change from the original HVAC system type selections. Instead, the redesign emphasis was placed on operating and control modifications, control of outside air, and use of heat recovery. However, potentially effective strategies such as modular boilers or plant equipment staging were not used.

The most frequently employed control strategy was the changing of night heating setpoint to 60 F or less and the cooling setpoint to 78 F or more. Daytime heating setpoints were lowered to 68 F in several of the secondary schools, but in only two of the elementary schools. For control of unoccupied space heating, seven-day timeclocks were often installed on hot-water circulating pumps to restrict operation to regular occupied periods, and hot water temperatures were reset to match changing space heating loads.

Ventilation air quantities were reassessed and reduced where practical, which often allowed the use of smaller fan motors. In some instances, controls were installed to keep outside air dampers closed for the morning warm-up cycle, and ventilation fans were interlocked with heating controls to shut them off during unoccupied periods. Kitchen hoods were modified in some schools to provide unconditioned make-up air to the hood exhaust.

Other system strategies included reduction of air system static pressures and the use of evaporative coolers in hot, dry climates. Heat recovery applications in all climates were found in more than one-third of school redesigns. Four of these applications involved heat recovery (double-bundle) chillers used to preheat ventilation air and service hot water. The remainder included exhaust air heat recovery from locker rooms and general building exhaust.

Observations and conclusions

The homogeneity and geographic representation in the school sample adds confidence to the energy effectiveness evident in the redesign solutions. Indeed, the energy savings would have been even greater were it not for the limitations of the energy analysis method for evaluating the widespread use of daylighting strategies. Modifications to building plan, form, and envelope to control conduction not only addressed the dominant unoccupied status of school spaces, but also accommodated a variety of complementary natural lighting and solar control schemes for occupied use. Fundamental architectural concepts were coordinated with well-controlled mechanical systems to meet both full- and part-load conditions efficiently. □

b. Building Type Analysis: Elementary and Secondary Schools

This section supplements the information already covered in the School article ("Energy: A Class By Itself", Progressive Architecture Magazine, March, 1983) by providing additional detail on the most recurrent strategies used in elementary and secondary school redesigns. Energy targets, conservation opportunities and overall redesign schemes found in schools are discussed in more detail in the article.

The great majority of the buildings in the schools sample were concerned with both minimizing the impact of conduction during unoccupied periods, and reducing lighting loads. Berming and daylighting were the two most commonly found strategies used to address these two issues. The following material provides details as to how such strategies were actually implemented and integrated with other building systems.

5.1 Berming

The use of earth as a natural insulator was found in nearly all the school redesigns. However, the degree to which berming was used varied considerably from building to building. In some instances, only that portion of the first story wall up to the window sill was bermed. More ambitious schemes bermed one and two stories high. An extreme example is a school located in San Antonio, TX. The building shape was squared in order to minimize the envelope surface area and all fenestration was eliminated. The two floors housing classrooms and administration support facilities were bermed on the south, east and west, and buffered on top by an unconditioned gymnasium. Additionally, a variety of non-conditioned spaces were placed on the perimeter for increased protection.

It is the authors opinion that berming carried to this extreme is an inappropriate action for any building type, except perhaps a defense installation where an earth covering has a specific purpose. In most cases, one can question the cost effectiveness of berming for buildings with sizable internal loads (such as schools). Berming may be desired for aesthetic purposes, but usually there are more cost effective thermal resistance and mass measures which may be used.

Not so extreme examples are illustrated below (See Figure 6.11). All berming applications must include provisions for adequate water drainage at the wall surface. For that purpose, permeable

materials, such as sand and/or gravel, are placed on the wall's perimeter in conjunction with a French drain system and waterproofed walls.

Note that when a story or more are bermed, not only are additional excavation costs incurred, but retaining walls become necessary to contain the lateral pressure exerted by the ground. The cases illustrated show placement of the insulation, at either the interior or the exterior wall perimeter, or at the wall interior.

5.2 Natural Lighting

Another recurrent theme was daylighting in all its forms: north/south clerestories, monitors, skylights, sun scoops, windows, etc. The source of daylight was quite important in determining the internal spatial organization of the building. Most designers using side daylighting placed classrooms on the perimeter with interior circulation wrapped around an administration and service core. Buildings using clerestories placed classrooms on the interior and buffer areas along the perimeter.

Sophisticated daylighting solutions were not prevalent in the redesigns but we do include in the examples some of the better strategies applied.

Some increase in the use of photo cells was noted, but local switching remained the main form of control in daylit classrooms. There were very few sophisticated applications of lighting controls. For example, simple measures such as perimeter switching and 2-3 level switching were not used. It is clear that such strategies have evolved over the last few years into cost effective lighting control options.

Daylighting offers not only the opportunity to build schools that consume less energy, but to also build schools that provide environments more conducive to learning. Several studies have shown that students respond favorably to natural light.

Illustrated below are three predominant daylighting techniques used during the redesign process (See Figure 6.12). These include a sawtooth clerestory system; a daylight borrowing scheme; and a side lighting system (two additional clerestory systems are illustrated in the Schools article), all of which are viable design solutions.

KEY

① ELEMENTARY

1 SECONDARY

↑ BUILDING I.D. NUMBER

FIGURE 5.1. Schools

FIGURE 5.2. Frequency of Strategies Schools

FIGURE 5.3. Conduction - Schools and Secondary Schools

FIGURE 5.4. Solar Control - Schools

FIGURE 5.5. Lighting - Schools

KEY:

- NOT SIGNIFICANT
- ENTHALPY
- DRY BULB

HVG - H & V GRAVITY HEATING
 CVSD - CONSTANT VOLUME SINGLE AIR DUCT
 VAV - VARIABLE AIR VOLUME
 HP - HEAT PUMP
 DD - DUAL DUCT
 UCU - UNIT AIR CONDITIONING
 CIND - CEILING INDUCTION
 2PFC - 2 PIPE FAN COIL
 4PFC - 4 PIPE FAN COIL/UNIT VENTILATION

- 1. HEATING
 BOILER, FURNACE
 DIRECT CONVERSION
- 2. COOLING
 REFRIDGERATION
 DIRECT CONVERSION
- 3. COMBINATION
 HEATING & COOLING
 DOUBLE BUNDLE
 CONDENSER,
 HEAT PUMP

FIGURE 5.6. Primary and Secondary Systems - Schools

FIGURE 5.7. HVAC Set Points - Schools

KEY:

* REDESIGN GREATER THAN 600

FIGURE 5.8. Equipment Efficiencies - Schools

FIGURE 5.9A. Miscellaneous Energy Parameters

FIGURE 5.9B. Miscellaneous Energy Parameters

FIGURE 5.9C. Miscellaneous Energy Parameters

FIGURE 5.10. Space Use and Cost Change Schools

FIGURE 5.11. Berming: School Redesign Examples
School Redesign Wall Section (4 Columbus, OH)

FIGURE 5.12A. Daylighting School Redesign (4 Columbus, OH)
 Building #4, Columbus, OH: This side lighting scheme used curvi-linear reflective sills and soffits on tilted glass windows to bounce light as deep as possible into the space.

FIGURE 5.12B. Daylighting School Redesign. (1 Minneapolis MN)
 Building #1, Minneapolis, MN: This redesign illustrates the use of a vented atrium for daylight borrowing purposes. Motorized insulated panels are used to mitigate night heat losses.

FIGURE 5.12C. Natural Lighting: School Redesign Examples. Daylighting School Redesign (1 Dallas, TX) Building #8, Dallas, TX: This sawtooth daylighting scheme relies (from a structural standpoint) on a long span truss system. The clerestories face south for added daylight gains (vertical surfaces facing the sun receive more light from the sky even if shaded from the direct rays of the sun). Overhangs prevent undesirable direct solar gains. Roll down cloth shades are used for glare control and pendant mounted light fixtures at the base of the sawtooth supplement daylighting. For the Dallas climate north facing clerestories may have been just as advantageous but this alternative was not modeled.

KEY ENERGY PARAMETERS
EXTRACTIONS FROM COMPUTER STORED DATA

BEPS PHASE II KEY DATA BASE PARAMETER: CLINICS
ENVELOPE

04-JAN-83
PAGE 1

P.A. NO.	BLDG NO.	FLOOR AREA		ORIENT. DEG. FRN NORTH	MAJOR ORIENT.	WINTER INF. (ACH)	WALL BELOW GRADE	U-VALUES				BLDG MASS (LB/SF)			BLDG COLOR	
		GROSS	NET					WALL	ROOF	GLASS	COMPOSITE	WALL	ROOF	FLOOR	WALL	ROOF
1	R2	13575.	11472.	0	E-W	0.28	11.	0.10	0.04	0.78	0.10	64.5	13.2	55.3	M	M
	582	14904.	13200.	0	E-W	0.01	46.	0.05	0.04	0.83	0.06	64.5	13.2	55.3	M	M
2	R7	8624.	7980.	0	E-W	0.20	35.	0.05	0.05	0.38	0.09	6.6	7.1	3.6	L	D
	567	8658.	8236.	0	E-W	0.20	40.	0.04	0.04	0.56	0.09	4.7	7.1	3.6	L	L
3	67	28478.	27688.	0	N-S	0.70	0.	0.07	0.05	0.60	0.13	46.0	7.3	66.0	D	M
	567	27738.	27538.	0	E-W	0.70	16.	0.06	0.06	0.56	0.11	75.4	72.0	66.0	L	L
4	46	6307.	6075.	21	E-W	0.75	0.	0.05	0.04	0.60	0.11	13.2	13.3	51.0	M	M
	546	6345.	6156.	350		0.62	88.	0.05	0.03	0.60	0.09	54.9	14.5	51.0	L	L
5	50	13830.	12130.	0	N-S	0.25	25.	0.09	0.14	1.10	0.19	98.0	13.5	50.0	M	M
	550	13891.	12168.	0		0.25	39.	0.07	0.04	0.55	0.08	100.0	17.5	50.0	M	M
6	121	51800.	45550.	16	N-S	0.15	8.	0.26	0.22	1.04	0.31	51.2	25.0	50.0	M	L
	621	57500.	53180.	16	N-S	0.09	20.	0.22	0.04	0.61	0.16	89.2	12.0	50.0	M	L
7	19	97100.	71200.	315	E-W	0.33	13.	0.10	0.08	0.50	0.13	73.6	102.0	100.0	L	L
	119	149930.	132303.	45		0.60	12.	0.20	0.10	0.57	0.31	65.1	90.0	72.0	M	D
8	134	40310.	37831.	0	E-W	0.75	17.	0.52	0.08	1.13	0.18	80.0	8.0	47.0	M	M
	634	42560.	38550.	0	E-W	0.75	44.	0.52	0.08	1.13	0.22	80.0	8.0	47.0	M	M
9	140	225000.	99540.	0	E-W	0.00	0.	0.18	0.11	1.13	0.14	100.0	150.0	150.0	M	L
	640	108835.	99431.	0	E-W	0.00	0.	0.07	0.10	1.13	0.09	100.0	150.0	150.0	M	L
10	143	225000.	76000.	45	N-S	1.00	0.	0.15	0.10	0.81	0.28	49.0	80.0	80.0	D	L
	643	230000.	78400.	45	N-S	1.00	0.	0.07	0.10	0.81	0.16	14.9	66.7	80.0	L	L
MEAN ORIGINAL DESIGN		71002.	39547.	40.		0.44	11.	0.16	0.09	0.81	0.16	58.2	41.9	65.3		
MEAN REDESIGN		66036.	46916.	46.		0.42	30.	0.13	0.06	0.74	0.14	64.9	45.1	62.5		

REPS PHASE II KEY DATA BASE PARAMETER: CLINICS
ENVELOPE

04-JAN-83
PAGE 2

P.A. NO.	BLDG NO.	BLDG GLASS AREAS				SKYLIGHT AREA (SQ.FT)	GLASS SHADE COEFFICIENT				EXT SHADE	PROCESS LOADS			
		SQ FT	ENVELOPE	SOUTH	NORTH		SOUTH	NORTH	EAST	WEST		GENERAL KW/SF	BTUH/SF	SPECIAL KW/SF	BTUH/SF
1	92	502.	9.	16.	65.	1.	0.90	0.90	0.90	0.90		0.000	0.0	0.000	0.0
	582	173.	4.	38.	52.	1.	0.90	0.90	0.90	0.00		0.000	0.0	0.000	0.0
2	97	696.	17.	25.	31.	0.	0.55	0.55	0.55	0.00	YES	0.000	0.0	0.348	0.0
	587	681.	19.	99.	0.	0.	1.00	0.00	1.00	0.00		0.000	0.0	0.001	0.0
3	67	3749.	26.	5.	0.	0.	0.60	0.00	0.60	0.60	YES	0.001	0.0	0.000	0.0
	567	2528.	18.	57.	47.	0.	0.60	0.60	0.60	0.00	YES	0.001	0.0	0.000	0.0
4	46	1165.	22.	14.	60.	1.	0.47	0.78	0.78	0.00		0.000	0.0	0.000	0.0
	546	694.	58.	0.	100.	0.	0.00	0.78	0.00	0.00		0.000	0.0	0.000	0.0
5	50	1064.	12.	12.	12.	0.	0.47	0.47	0.47	0.47		0.001	0.0	0.000	0.0
	550	416.	8.	12.	0.	1.	0.70	0.00	0.52	0.47		0.001	0.0	0.000	0.0
6	121	4302.	15.	12.	27.	0.	0.70	0.70	0.70	0.70	YES	0.000	0.0	0.001	0.1
	621	2660.	13.	22.	19.	0.	0.86	0.70	0.70	0.70	YES	0.000	0.0	0.001	0.1
7	19	3590.	23.	0.	78.	1.	0.00	0.29	0.00	0.29	YES	0.001	0.0	0.001	0.0
	119	26296.	40.	33.	30.	0.	0.51	0.51	0.51	0.51	YES	0.000	0.0	0.002	0.0
8	134	776.	8.	28.	38.	0.	1.00	1.00	1.00	1.00	YES	0.000	0.0	0.002	0.0
	634	804.	13.	37.	25.	1.	1.00	1.00	1.00	1.00	YES	0.000	0.0	0.002	0.0
9	140	85.	0.	0.	100.	0.	0.00	0.70	0.00	0.00		0.000	0.0	0.000	0.9
	640	96.	0.	0.	100.	0.	0.00	1.00	0.00	0.00		0.001	0.0	0.000	1.8
10	143	11300.	28.	19.	27.	0.	0.45	0.45	0.45	0.45		0.001	0.0	0.000	0.0
	643	6600.	15.	12.	33.	0.	0.45	0.45	0.45	0.45	YES	0.001	0.0	0.000	0.0
MEAN ORIGINAL DESIGN		2723.	16.	13.	44.	0.	0.64	0.65	0.68	0.63		0.001	0.0	0.035	0.1
MEAN REDESIGN		4095.	19.	31.	40.	0.	0.75	0.74	0.71	0.63		0.000	0.0	0.001	0.2

BEPS PHASE II KEY DATA BASE PARAMETER: CLINICS
LIGHTING SYSTEM

04-JAN-83
PAGE 3

P.A. NO.	R.DG NO.	WATTS PER S.F.	ILLUM. LEVEL	LAMP TYPE (PERCENT TOTAL FLOOR AREA)								CONTROL TYPE (% TOTAL FLOOR AREA)							
				INC	TH	F	HG	MH	HPS	LPS	U	BKP	SH	LV	CPTR	PH	DIA	IC	U
1	82	2.8	63.	36.	0.	64.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	582	2.3	63.	32.	0.	68.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
2	87	2.0	102.	15.	0.	85.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	587	0.9	56.	22.	0.	78.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
3	67	1.7	26.	49.	0.	44.	8.	0.	0.	0.	0.	5.	91.	0.	0.	0.	1.	2.	0.
	567	1.1	31.	52.	0.	38.	0.	0.	10.	0.	0.	0.	90.	0.	0.	0.	0.	10.	0.
4	46	4.3	66.	56.	0.	44.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	546	1.7	26.	99.	0.	0.	0.	0.	0.	0.	0.	0.	99.	0.	0.	0.	0.	0.	0.
5	50	1.5	42.	57.	0.	43.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	550	1.6	47.	24.	0.	76.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
6	121	2.5	76.	4.	0.	96.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	421	1.1	38.	1.	0.	99.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	100.
7	19	2.0	48.	19.	0.	72.	9.	0.	0.	0.	0.	2.	46.	0.	0.	0.	0.	1.	0.
	119	1.0	15.	96.	0.	4.	0.	0.	0.	0.	0.	0.	95.	0.	0.	0.	0.	5.	0.
8	134	2.5	80.	4.	0.	96.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	634	1.5	80.	24.	0.	76.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
9	140	2.3	89.	1.	0.	99.	0.	0.	0.	0.	0.	1.	99.	0.	0.	0.	0.	0.	0.
	640	1.7	90.	100.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
10	143	3.1	59.	1.	0.	99.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	643	2.0	30.	54.	0.	46.	0.	0.	0.	0.	0.	0.	49.	0.	0.	0.	0.	51.	0.
MEAN ORIGINAL DESIGN		2.5	65.	24.	0.	74.	2.	0.	0.	0.	0.	1.	99.	0.	0.	0.	0.	0.	0.
MEAN REDESIGN		1.5	48.	51.	0.	48.	0.	0.	1.	0.	0.	0.	83.	0.	0.	0.	0.	7.	10.

P.A. NO.	BLDG NO.	SYSTEM ID		T-STAT SET PT.				COOL	DAY	NIGHT	NIGHT	DEAD	HEAT	TEMP	HEAT	RECOVERY	CFM/SF	CFM	OUTSIDE AIR		ECON TYPE
		INT	PER	HEAT	HEAT	HEAT	BAUD												TO PA	CIRL	
1	R2	3	3	75.	70.	65.	YES	0.	0.				0.	0.	1.11	0.84	832.	10.	1208.	22.	60.
	SR2	5	5	75.	72.	65.	YES	0.	60.	NO			0.	0.	1.22	1.22	921.	10.	1734.	31.	
2	R7	3	3	78.	68.	68.	YES	0.	10.				0.	0.	0.83	0.53	2084.	10.	625.	11.	ENTH
	SR7	15	15	78.	68.	58.	YES	7.	5.				0.	0.	1.00	1.00	5491.	10.	824.	12.	
3	R7	3	7	78.	75.	60.	YES	3.	0.				0.	0.	1.80	0.68	1029.	10.	3953.	66.	ENTH
	SR7	3	7	78.	72.	60.	YES	6.	0.				0.	0.	1.13	0.83	1344.	10.	2859.	48.	
4	Rn	0	15	78.	75.	75.	YES	0.	30.				0.	0.	1.44	0.00	5639.	10.	868.	19.	
	SR4	0	15	78.	71.	65.	YES	0.	0.				0.	0.	1.17	0.00	1333.	10.	720.	16.	
5	R0	3	3	75.	72.	62.	YES	0.	40.				0.	0.	1.36	0.52	1363.	15.	1841.	46.	ENTH
	SR5	0	5	75.	72.	62.	YES	0.	60.	NO			0.	0.	0.50	0.00	766.	8.	474.	7.	
6	R21	1	1	75.	70.	60.	YES	0.	86.				0.	0.	1.13	1.07	222.	14.	7201.	9.	55.
	SR21	4	1	78.	72.	55.	YES	0.	70.				0.	0.	0.46	0.46	1166.	8.	1958.	2.	
7	R9	15	15	75.	75.	55.	YES	0.	0.				100.	70.	0.97	0.95	1479.	22.	15073.	30.	
	SR7	7	7	52.	75.	75.	YES	0.	0.				0.	0.	0.09	1.08	2494.	65.	17073.	74.	
8	R34	0	3	78.	72.	55.	NO	0.	0.				0.	0.	1.31	0.00	588.	10.	4941.	13.	65.
	SR34	4	5	78.	72.	55.	NO	0.	0.	NO			0.	0.	1.27	1.03	936.	10.	4561.	12.	
9	R40	1	1	75.	75.	75.	YES	0.	0.				0.	0.	1.12	0.77	495.	20.	19620.	20.	ENTH
	SR40	5	5	75.	70.	75.	NO	5.	50.	NO			0.	0.	0.50	0.50	755.	40.	19991.	20.	
10	R43	5	5	75.	75.	0.	NO	0.	30.	NO			0.	0.	1.86	0.59	1076.	11.	10117.	14.	55.
	SR43	5	5	75.	75.	0.	NO	0.	30.	NO			0.	0.	1.17	0.50	884.	15.	9835.	14.	
MEAN ORIGINAL DESIGN				76.	73.	58.		3.	39.				10.	7.	1.29	0.74	1481.	13.	6545.	25.	
MEAN REDESIGN				74.	72.	57.		6.	46.				0.	0.	0.85	0.83	1609.	19.	6003.	24.	

HEPS PHASE II KEY DATA BASE PARAMETER: CLINICS
PRIMARY SYSTEM

UK-1AM-R3
PAGE 5

P.A. NO.	BLDG. NO.	CHILLER COOLING COP	HEATING EFF.	HEAT RECOVERY	HEAT PUMP TYPE	HP HEATING COP	COOLING FUEL TYPE	HOT WATER STORAGE (BTU/RTU CAP)	ANX. KW COOLING VAR.	ANX. KW COOLING CONST	ANX. KW HEATING VAR.	ANX. KW HEATING CONST	S.F. PER TON	HEATING BTU PER SF
1	82 582	2.3 2.4	0.7 0.8			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	130. 533.	72. 8.
2	87 587	3.2 2.3	0.0 0.0			0.0 0.0	E E	0. 0.	0. 1.	2. 0.	0. 0.	0. 0.	456. 824.	0. 0.
3	67 567	2.2 2.8	0.8 0.8	YES		0.0 0.0	E E	0. 0.	0. 9.	0. 4.	2. 6.	0. 0.	264. 318.	52. 24.
4	46 546	2.2 2.0	0.0 1.0			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	288. 341.	0. 2.
5	50 550	2.2 5.2	0.8 0.8			0.0 0.0	E E	0. 0.	0. 11.	0. 0.	0. 0.	0. 2.	404. 515.	62. 30.
6	121 621	1.0 1.0	1.0 1.0			0.0 0.0	I I	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	944. 887.	15. 12.
7	19 119	3.1 1.7	1.0 0.8		11	3.3 0.0	E E	3. 0.	19. 0.	39. 0.	0. 7.	0. 0.	0. 295.	1. 58.
8	134 634	2.1 2.8	1.0 1.0			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	296. 335.	33. 31.
9	140 640	3.0 3.4	0.8 0.8			0.0 0.0	E E	0. 0.	26. 33.	30. 15.	7. 2.	0. 0.	286. 473.	32. 8.
10	143 643	3.7 4.3	0.8 0.8			0.0 0.0	E E	0. 0.	0. 0.	23. 18.	0. 0.	0. 0.	368. 519.	20. 11.
MEAN ORIGINAL DESIGN		2.6	0.9	0		3.3		3.	5.	9.	1.	0.	404.	29.
MEAN REDESIGN		2.8	0.9	1		0.0		0.	5.	4.	1.	0.	504.	18.

BEPS PHASE II KEY DATA BASE PARAMETER: HOSPITALS
ENVELOPE

04-JAN-83
PAGE 1

P.A. NO.	BLDG NO.	FLOOR AREA		ORIENT. DEG. FROM NORTH	MAJOR ORIENT.	WINTER INF. (ACH)	WALL BELOW GRADE	U-VALUES				BLDG MASS (LB/SF)			BLDG COLOR	
		GROSS	NET					WALL	ROOF	GLASS	COMPOSITE	WALL	ROOF	FLOOR	WALL	ROOF
11	52	318800.	227146.	45		0.00	13.	0.32	0.20	0.49	0.28	103.4	115.0	105.0	M	L
	552	335000.	259200.	0		0.00	28.	0.09	0.10	0.49	0.13	105.0	80.0	105.0	L	L
12	53	345820.	298556.	0		0.00	13.	0.13	0.11	0.58	0.14	88.5	53.0	63.0	D	L
	553	362672.	298556.	0		0.00	38.	0.05	0.07	0.45	0.09	89.0	96.0	63.0	D	L
13	88	258700.	242053.	315	N-S	0.30	14.	0.07	0.20	0.56	0.18	90.0	30.0	60.0	M	D
	588	228600.	172032.	0	E-W	0.30	12.	0.05	0.05	0.53	0.10	90.0	30.0	60.0	L	L
15	55	79500.	72800.	0	E-W	0.20	24.	0.06	0.16	0.55	0.11	8.2	25.0	67.0	L	M
	555	87871.	81800.	0		0.00	24.	0.07	0.16	0.55	0.14	22.5	25.0	67.0	L	M
16	30	84170.	77209.	0		2.00	0.	0.06	0.04	0.55	0.07	44.6	14.0	50.0	M	M
	530	75082.	68575.	0		0.20	7.	0.06	0.02	0.55	0.07	80.0	13.2	50.0	M	M
17	15	66500.	50240.	0	N-S	1.50	22.	0.15	0.06	0.54	0.15	123.5	48.5	60.0	M	M
	515	66500.	54640.	0		1.30	21.	0.07	0.05	0.54	0.09	123.5	48.5	60.0	M	M
18	111	81986.	63840.	0	E-W	0.15	3.	0.11	0.18	1.13	0.19	47.3	61.2	100.0	M	M
	611	80800.	65824.	0	E-W	0.12	0.	0.06	0.08	0.48	0.10	122.0	80.0	70.0	M	L
19	95	86300.	84500.	0	N-S	0.50	0.	0.06	0.15	1.13	0.18	55.0	15.0	50.0	D	M
	595	106000.	91000.	0	E-W	0.50	0.	0.06	0.08	0.60	0.10	90.0	25.0	75.0	L	M
20	96	77500.	77047.	0		0.20	0.	0.07	0.15	0.55	0.15	13.8	46.0	46.0	L	M
	596	79456.	76674.	0		0.10	80.	0.15	0.10	0.55	0.15	50.9	50.0	75.0	L	L
21	141	145200.	120000.	345		0.00	8.	0.09	0.10	1.13	0.19	120.0	120.0	120.0	M	M
	641	145100.	123640.	10		0.00	0.	0.05	0.10	1.10	0.15	120.0	120.0	120.0	L	L
MEAN ORIGINAL DESIGN		154448.	131339.	71.		0.48	10.	0.11	0.13	0.72	0.17	69.4	52.8	72.1		
MEAN REDESIGN		156708.	129194.	1.		0.25	21.	0.07	0.08	0.58	0.11	89.3	56.8	74.5		

NOTE: DATA FOR BLDG #14 - 90/590 NOT AVAILABLE

HEPS PHASE II KEY DATA BASE PARAMETER: HOSPITALS
ENVELOPE

04-JAN-83
PAGE 2

P.A. NO.	BLDG NO.	BLDG GLASS AREAS				SKYLIGHT AREA (%ROOF)	GLASS SHADE COEFFICIENT				FXI SHADE	PROCESS LOADS			
		SQ FT	%ENVEL	%SOUTH	%NORTH		SOUTH	NORTH	EAST	WEST		GENERAL KW/SF	BTUH/SF	SPECIAL KW/SF	BTUH/SF
11	52	15888.	18.	55.	31.	0.	0.33	0.33	0.33	0.33		0.001	0.0	0.000	0.0
	552	10367.	27.	38.	26.	0.	0.33	0.33	0.33	0.33	YES	0.001	0.0	0.000	0.0
12	53	8839.	11.	24.	23.	0.	0.52	0.52	0.52	0.52		0.000	0.0	0.001	0.0
	553	9809.	21.	20.	20.	0.	0.32	0.31	0.40	0.41		0.000	0.0	0.001	0.0
13	88	12989.	20.	18.	24.	0.	0.83	0.83	0.83	0.83		0.001	0.0	0.003	0.0
	588	9200.	20.	19.	38.	0.	0.21	0.21	0.21	0.21	YES	0.001	0.0	0.002	0.0
15	55	2100.	6.	30.	36.	0.	0.60	0.60	0.60	0.60	YES	0.000	0.0	0.005	8.8
	555	4740.	17.	39.	29.	1.	0.60	0.60	0.60	0.60	YES	0.000	0.0	0.004	8.0
16	30	5365.	11.	9.	14.	0.	0.65	0.65	0.65	0.65		0.000	0.0	0.007	0.0
	530	2406.	7.	33.	33.	2.	0.65	0.65	0.65	0.00	YES	0.000	0.0	0.008	0.0
17	15	1544.	6.	12.	11.	0.	0.54	0.54	0.54	0.54		0.001	0.0	0.013	0.0
	515	1522.	6.	12.	11.	0.	0.54	0.54	0.54	0.54	YES	0.001	0.0	0.012	0.0
18	111	3362.	8.	6.	51.	0.	0.91	0.91	0.91	0.91	YES	0.002	0.0	0.013	0.0
	611	3230.	8.	35.	65.	27.	0.40	0.40	0.00	0.00	YES	0.002	0.0	0.013	0.0
19	95	5945.	20.	8.	23.	0.	0.80	0.80	0.90	0.80		0.000	0.0	0.002	0.0
	595	3800.	14.	74.	8.	0.	0.90	0.60	0.60	0.60	YES	0.000	0.0	0.002	0.0
20	96	4085.	14.	31.	39.	0.	0.24	0.24	0.24	0.24		0.000	0.0	0.004	29.0
	596	2818.	44.	46.	23.	0.	0.50	0.50	0.50	0.50	YES	0.002	0.0	0.005	28.3
21	141	8428.	11.	29.	18.	7.	0.70	0.65	0.70	0.47	YES	0.001	0.0	0.002	0.0
	641	11267.	11.	26.	49.	0.	0.60	0.88	1.00	0.50		0.001	0.0	0.002	26.2
MEAN ORIGINAL DESIGN		6855.	13.	22.	27.	1.	0.61	0.61	0.62	0.59		0.001	0.0	0.005	3.8
MEAN REDESIGN		5916.	16.	34.	30.	3.	0.50	0.50	0.54	0.46		0.001	0.0	0.005	6.2

NOTE: DATA FOR BLDG #14 - 90/590 NOT AVAILABLE

REPS PHASE II KEY DATA BASE PARAMETER: HOSPITALS
LIGHTING SYSTEM

04-JAN-83
PAGE 3

P.A. NO.	BLDG NO.	WATTS		ILLUM. LEVEL	LAMP TYPE (PERCENT TOTAL FLOOR AREA)								CONTROL TYPE (% TOTAL FLOOR AREA)							
		PER S.F.			INC	TH	F	HG	MH	RPS	LPS	0	RKH	SH	LV	CPTR	PH	Dir	TC	U
11	52	1.8	33.	7.	0.	92.	1.	0.	0.	0.	0.	0.	1.	99.	0.	0.	0.	0.	0.	0.
	552	1.7	35.	5.	0.	90.	0.	0.	0.	0.	0.	0.	0.	99.	0.	0.	0.	0.	0.	0.
12	53	2.9	80.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.	88.	0.	0.	0.	0.	12.	0.
	553	2.9	80.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.	89.	0.	0.	0.	0.	11.	0.
13	88	1.4	77.	40.	0.	53.	0.	0.	0.	0.	0.	0.	0.	93.	0.	0.	0.	0.	0.	0.
	588	1.6	88.	21.	0.	79.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
15	55	1.5	52.	1.	0.	99.	0.	0.	0.	0.	0.	0.	24.	76.	0.	0.	0.	0.	0.	0.
	555	1.1	36.	0.	0.	100.	0.	0.	0.	0.	0.	0.	5.	95.	0.	0.	0.	0.	0.	0.
16	30	2.5	79.	11.	0.	62.	20.	0.	0.	0.	8.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	530	1.9	54.	5.	0.	87.	0.	0.	0.	0.	0.	8.	0.	100.	0.	0.	0.	0.	0.	0.
17	15	3.7	62.	0.	0.	100.	0.	0.	0.	0.	0.	0.	17.	81.	0.	0.	0.	0.	2.	0.
	515	2.6	44.	0.	0.	100.	0.	0.	0.	0.	0.	0.	2.	78.	21.	0.	0.	0.	0.	0.
18	111	2.8	63.	11.	0.	78.	11.	0.	0.	0.	0.	0.	29.	71.	0.	0.	0.	0.	0.	0.
	611	1.9	57.	4.	0.	92.	0.	5.	0.	0.	0.	0.	0.	64.	0.	0.	3.	0.	33.	0.
19	95	2.3	44.	24.	0.	76.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	595	1.7	44.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.	74.	0.	0.	0.	0.	26.	0.
20	96	1.6	51.	14.	0.	86.	0.	0.	0.	0.	0.	0.	0.	99.	0.	0.	0.	1.	0.	0.
	596	1.4	53.	1.	0.	95.	0.	0.	0.	4.	0.	0.	0.	84.	0.	0.	16.	0.	0.	0.
21	141	2.8	50.	24.	0.	76.	0.	0.	0.	0.	0.	0.	9.	91.	0.	0.	0.	0.	0.	0.
	641	2.6	49.	26.	0.	73.	0.	0.	0.	0.	0.	0.	8.	91.	0.	0.	0.	0.	1.	0.
MEAN ORIGINAL DESIGN		2.4	59.	13.	0.	82.	3.	0.	0.	1.	0.	0.	8.	90.	0.	0.	0.	0.	1.	0.
MEAN REDESIGN		1.9	54.	6.	0.	91.	0.	1.	0.	0.	1.	1.	1.	87.	2.	0.	2.	0.	7.	0.

NOTE: DATA FOR BLDG #14 - 90/590 NOT AVAILABLE

REPS PHASE II KEY DATA BASE PARAMETERS: HOSPITALS
SECONDARY SYSTEM

04-JAN-83
PAGE 4

P.A. NO.	BLDG NO.	SYSTEM ID		T-STAT SET PT.				DEAD HAND	HEAT TO PA	TEMP CTRL	EXHAUST AIR		SUPPLY		CFM PER HP	OUTSIDE AIR			ECOM TYPE
		INT	PER	COOL	DAY	NIGHT	NIGHT				HEAT RECOVERY	VENT	EFF	CFM/SE		%	CFM	CFM/PER	
11	52	3	3	75.	75.	75.	YES	0.	0.		0.	0.	0.98	1.85	515.	45.	141178.	66.	70.
	552	1	1	75.	75.	75.	YES	0.	0.	NO	0.	0.	0.69	1.18	489.	33.	78867.	81.	
12	53	3	10	75.	75.	75.	YES	3.	0.		0.	0.	1.11	1.04	693.	32.	102251.	85.	
	553	3	1	75.	75.	75.	YES	0.	0.	NO	0.	0.	0.65	1.23	562.	47.	101763.	84.	55.
13	84	5	3	75.	75.	75.	YES	0.	20.	NO	0.	0.	0.94	1.33	997.	44.	113448.	183.	
	584	5	5	78.	72.	72.	YES	6.	20.	NO	0.	0.	1.23	1.22	1658.	45.	94609.	109.	ENTH
15	55	3	15	75.	75.	75.	YES	0.	0.		0.	0.	1.24	0.67	372.	20.	14901.	55.	
	555	5	12	75.	75.	75.	YES	0.	0.	NO	0.	0.	0.85	0.61	912.	24.	17312.	67.	
16	30	3	2	78.	70.	65.	YES	0.	0.		0.	0.	1.31	0.43	1426.	36.	13365.	94.	55.
	530	0	14	78.	70.	65.	YES	0.	0.		44.	70.	0.88	0.00	658.	16.	9435.	27.	ENTH
17	15	10	5	75.	70.	60.	YES	0.	55.	NO	72.	60.	1.56	1.41	849.	49.	37703.	215.	
	515	5	5	75.	70.	70.	YES	0.	55.	NO	68.	60.	1.38	1.20	944.	48.	34378.	57.	
18	111	1	1	75.	75.	75.	YES	0.	10.		0.	0.	1.60	1.07	402.	39.	37128.	80.	55.
	611	1	1	76.	72.	72.	YES	4.	20.	NO	93.	74.	0.93	0.83	426.	69.	39388.	127.	ENTH
19	95	0	3	75.	75.	75.	YES	0.	0.		0.	0.	1.45	0.00	1591.	19.	23040.	71.	
	595	12	12	75.	75.	75.	YES	0.	10.		0.	0.	1.15	0.86	2250.	25.	24855.	52.	
20	96	0	1	75.	75.	75.	YES	0.	0.		0.	0.	1.62	0.00	1428.	32.	40488.	108.	55.
	596	3	5	75.	75.	0.	YES	0.	0.	NO	0.	0.	1.36	1.15	1040.	29.	28190.	161.	50.
21	141	3	3	75.	72.	72.	YES	0.	0.		0.	0.	1.39	0.68	752.	100.	139240.	169.	
	641	5	5	75.	72.	72.	YES	0.	0.	NO	0.	0.	1.37	0.97	882.	34.	51178.	41.	ENTH
MEAN ORIGINAL DESIGN				75.	74.	72.		3.	28.		7.	6.	1.34	1.06	903.	42.	68274.	113.	
MEAN REDESIGN				76.	73.	65.		5.	26.		21.	20.	1.05	1.03	982.	37.	47998.	81.	

NOTE: DATA FOR BLDG #14 - 90/590 NOT AVAILABLE

REPS PHASE II KEY DATA BASE PARAMETER: HOSPITALS
PRIMARY SYSTEM

06-JAN-83
PAGE 5

P.A. NO.	BLDG. NO.	CHILLER COOLING CAP	HEATING EFF.	HEAT RECOVERY	HEAT PUMP TYPE	HP HEATING COP	COOLING FUEL TYPE	HOT WATER STORAGE (RTU/RTU CAP)	AUX. KW COOLING VAP.	CONST	AUX. KW HEATING VAR.	CONST	S.F. PER TON	HEATING BTU PER SF
11	52	4.5	0.8			0.0	E	0.	247.	80.	27.	38.	123.	240.
	552	4.1	0.8	YES		0.0	E	0.	90.	30.	0.	26.	236.	149.
12	53	4.7	0.8			0.0	E	0.	324.	47.	94.	15.	203.	80.
	553	4.7	0.8			0.0	E	0.	324.	47.	94.	15.	204.	40.
13	48	3.5	0.8			0.0	E	0.	131.	56.	50.	10.	256.	82.
	548	4.3	0.8			0.0	E	0.	54.	80.	30.	5.	247.	77.
15	55	2.6	1.0		11	2.9	E	0.	8.	34.	0.	0.	425.	16.
	555	4.1	0.0	YES		0.0	E	0.	0.	36.	0.	0.	327.	0.
16	30	3.0	0.7			0.0	E	0.	33.	35.	6.	0.	130.	105.
	530	2.4	0.8			0.0	E	0.	0.	24.	0.	6.	192.	30.
17	15	1.0	1.0			0.0	I	0.	0.	0.	0.	0.	111.	132.
	515	1.0	1.0			0.0	I	0.	0.	10.	2.	2.	162.	196.
18	111	1.0	1.0			0.0	I	0.	23.	0.	6.	0.	44.	533.
	611	1.0	1.0			0.0	I	0.	0.	17.	0.	9.	176.	152.
19	95	2.4	1.0			0.0	E	0.	3.	0.	0.	0.	204.	47.
	595	0.0	0.0	YES		0.0	E	2000000.	6.	18.	0.	0.	423.	0.
20	96	3.4	0.8			0.0	E	0.	0.	54.	0.	22.	212.	120.
	596	4.1	0.8			0.0	E	0.	0.	48.	0.	22.	213.	87.
21	141	4.7	0.8			0.0	E	0.	32.	89.	43.	45.	187.	281.
	641	4.5	0.8			0.0	E	0.	23.	48.	24.	8.	320.	32.
MEAN ORIGINAL DESIGN		3.1	0.9	0		2.9		0.	80.	39.	23.	13.	190.	164.
MEAN REDESIGN		3.4	0.9	1		0.0		*****	49.	36.	15.	9.	256.	76.

NOTE: DATA FOR BLDG #14 - 90/590 NOT AVAILABLE

SUMMARY OF SECTION CONTENTS

- 5. Elementary and Secondary Schools
 - a. Article: "Energy: A Class By Itself"
 - b. Building Type Analysis
 - 5.1 Benchmarking
 - 5.2 Natural Lighting
 - c. Key Energy Parameters - Graphic Presentations
 - d. Key Energy Parameters - Extractions from Computer Stored Data

REPORT OF THE BOARD OF DIRECTORS

1. Financial and General Information
2. Board of Directors: A General Report
3. Financial Information
4. Financial Statements
5. Financial Statements - Detailed Information
6. Financial Statements - Detailed Information
7. Financial Statements - Detailed Information
8. Financial Statements - Detailed Information
9. Financial Statements - Detailed Information
10. Financial Statements - Detailed Information

KEY ENERGY PARAMETERS EXTRACTIONS FROM COMPUTER STORED DATA

REPS PHASE II KEY DATA BASE PARAMETER: ELEMENTARY SCHOOLS
ENVELOPE

04-JAN-83
PAGE 1

P.A. NO.	BLDG NO.	FLOOR AREA		ORIENT. DEG. FRM NORTH	MAJOR ORIENT.	WINTER INF. (ACH)	WALL FLOOR GRADE	U-VALUES				BLDG MASS (LB/SF)			BLDG COLOR	
		GROSS	NET					WALL	POOF	GLASS	COMPOSITE	WALL	ROOF	FLOOR	WALL	ROOF
1	77	66650.	62550.	0	E-W	0.75	0.	0.09	0.09	0.57	0.11	97.0	9.7	50.0	M	M
	577	72130.	72129.	0	E-W	0.75	69.	0.10	0.05	0.57	0.09	97.0	98.0	50.0	M	M
2	13	79700.	63300.	320	E-W	0.30	0.	0.13	0.05	0.68	0.09	45.0	7.0	50.0	M	M
	513	69700.	63400.	338	N-S	0.00	15.	0.07	0.02	0.49	0.08	202.0	9.0	93.0	M	L
3	59	18000.	16600.	145		0.75	0.	0.09	0.06	1.10	0.10	44.2	7.0	47.0	M	M
	559	19500.	18506.	0		0.00	21.	0.07	0.06	0.61	0.10	57.8	18.0	47.0	D	D
4	37	45670.	41970.	33	N-S	1.00	0.	0.07	0.08	1.10	0.09	98.9	69.0	48.0	M	M
	137	58800.	37210.	0	N-S	0.75	0.	0.09	0.04	1.13	0.28	12.6	10.0	140.0	L	M
5	128	63612.	62912.	0	E-W	0.50	13.	0.10	0.09	1.13	0.12	90.6	8.0	65.0	M	M
	628	55541.	54543.	315	N-S	0.50	33.	0.24	0.08	0.59	0.14	90.0	30.0	65.0	M	M
6	20	18690.	18610.	38		0.68	0.	0.08	0.05	0.56	0.09	52.5	18.8	14.0	M	L
	520	18025.	17835.	30	N-S	0.35	0.	0.08	0.05	0.56	0.10	51.2	18.8	14.0	M	L
7	23	79600.	79022.	25		0.12	0.	0.13	0.10	1.13	0.20	87.4	55.0	49.5	M	L
	523	82732.	78488.	0		0.12	0.	0.14	0.10	0.55	0.15	83.0	55.0	49.5	M	L
8	103	52279.	47359.	45	N-S	0.75	0.	0.11	0.20	1.13	0.21	45.8	30.0	62.0	D	M
	603	49866.	46313.	337		0.75	26.	0.08	0.09	0.69	0.14	14.5	20.0	62.0	L	L
9	146	55400.	54500.	15		0.70	10.	0.27	0.05	1.13	0.13	63.1	15.0	24.0	M	M
	646	58100.	57920.	0	E-W	0.70	49.	0.12	0.03	0.60	0.05	72.9	51.0	24.0	L	L
10	136	45481.	38189.	0		0.00	0.	0.14	0.12	1.00	0.16	85.0	62.0	50.0	M	D
	636	43348.	37776.	0		0.45	0.	0.08	0.05	1.00	0.26	80.0	60.0	50.0	L	L
11	145	44900.	42734.	25	N-S	0.40	13.	0.64	0.07	1.10	0.33	90.0	85.0	120.0	M	M
	645	44900.	42736.	11	N-S	0.40	13.	0.24	0.04	1.10	0.16	90.0	85.0	120.0	M	L
MEAN ORIGINAL DESIGN		50948.	47978.	77.		0.54	3.	0.17	0.09	0.97	0.15	72.7	33.3	52.7		
MEAN REDESIGN		52058.	47896.	94.		0.43	21.	0.12	0.06	0.72	0.14	77.4	41.3	65.0		

REPS PHASE II KEY DATA BASE PARAMETER: ELEMENTARY SCHOOLS
ENVELOPE

04-JAN-83
PAGE 2

P.A. NO.	BLDG NO.	BLDG GLASS AREAS				SKYLIGHT AREA (%ROOF)	GLASS SHADE COEFFICIENT				EXT SHADE	PROCESS LOADS			
		SQ FT	%ENVELOPE	%SOUTH	%NORTH		SOUTH	NORTH	EAST	WEST		GENERAL Kk/SF	BTUH/SF	SPECIAL Kk/SF	BTUH/SF
1	77	3060.	11.	28.	27.	0.	0.54	0.54	0.54	0.54		0.000	0.0	0.000	3.8
	577	5750.	50.	76.	16.	0.	0.66	0.40	0.44	0.40	YES	0.000	0.0	0.000	3.5
2	13	2278.	11.	50.	31.	0.	0.65	0.65	0.65	0.10		0.000	0.0	0.000	0.0
	513	1690.	9.	29.	11.	7.	0.51	0.76	0.76	0.36	YES	0.000	0.0	0.000	2.2
3	59	685.	7.	24.	12.	0.	0.36	0.36	0.36	0.36	YES	0.000	0.0	0.001	0.0
	559	1010.	11.	67.	24.	2.	0.90	1.00	0.90	0.90	YES	0.000	0.0	0.001	0.0
4	37	865.	6.	21.	28.	0.	0.71	0.71	0.71	0.71		0.000	0.0	0.006	0.0
	137	6287.	32.	17.	17.	0.	1.00	1.00	1.00	1.00		0.001	0.0	0.003	1.0
5	128	2557.	11.	21.	46.	0.	0.95	0.95	0.95	0.95	YES	0.000	0.0	0.002	0.0
	628	1084.	6.	0.	17.	0.	0.00	0.55	0.55	0.55		0.000	0.0	0.002	0.0
6	20	1422.	21.	1.	1.	0.	1.00	1.00	0.65	0.65	YES	0.000	0.0	0.000	0.0
	520	1563.	20.	2.	3.	1.	0.64	0.64	0.64	0.64	YES	0.000	0.0	0.000	0.0
7	23	10562.	30.	42.	30.	0.	0.94	0.94	0.94	0.94		0.000	0.0	0.003	0.0
	523	9348.	28.	31.	34.	0.	0.80	0.80	0.80	0.80	YES	0.000	0.0	0.003	0.0
8	103	1960.	13.	22.	25.	0.	0.60	0.60	0.60	0.65	YES	0.000	0.0	0.001	0.0
	603	6093.	33.	88.	7.	0.	0.55	0.60	0.60	0.60	YES	0.000	0.0	0.002	0.0
9	146	959.	5.	22.	61.	0.	0.50	0.89	0.90	0.50	YES	0.000	0.0	0.000	0.0
	646	406.	4.	15.	67.	0.	0.50	0.50	0.50	0.90	YES	0.000	0.2	0.000	0.0
10	136	1310.	11.	0.	0.	0.	0.00	0.00	0.65	0.65	YES	0.000	0.0	0.001	0.0
	636	9414.	30.	0.	74.	0.	0.00	0.65	0.77	0.65	YES	0.000	0.0	0.000	0.0
11	145	2153.	10.	16.	19.	0.	0.65	0.65	0.65	0.65	YES	0.000	0.0	0.000	0.0
	645	1835.	9.	14.	28.	0.	0.64	0.64	0.64	0.64	YES	0.000	0.0	0.000	0.0
MEAN ORIGINAL DESIGN		2528.	12.	22.	25.	0.	0.69	0.73	0.69	0.61		0.000	0.0	0.001	0.3
MEAN REDESIGN		4043.	21.	31.	27.	1.	0.69	0.69	0.69	0.68		0.000	0.0	0.001	0.6

RFPS PHASE II KEY DATA BASE PARAMETER: ELEMENTARY SCHOOLS
LIGHTING SYSTEM

04-JAN-83
PAGE 3

P.A. NO.	R/DG FO.	WATTS		ILLUM. LEVEL	LAMP TYPE (PERCENT TOTAL FLOOR AREA)								CONTROL TYPE (% TOTAL FLOOR AREA)							
		S.F.	P.F.		INC	TH	F	HG	PH	HPS	LPS	O	RKR	SW	LV	CPTR	PH	DIM	IC	O
1	77	2.1	59.	1.	2.	85.	12.	0.	0.	0.	0.	0.	0.	98.	0.	0.	0.	0.	2.	0.
	577	1.3	40.	1.	0.	91.	1.	0.	8.	0.	0.	0.	0.	86.	0.	0.	11.	0.	0.	0.
2	13	3.0	72.	0.	0.	95.	5.	0.	0.	0.	0.	0.	5.	95.	0.	0.	0.	0.	0.	0.
	513	1.1	45.	0.	0.	88.	0.	7.	5.	0.	0.	0.	0.	50.	0.	0.	50.	0.	0.	0.
3	59	2.2	64.	5.	0.	80.	0.	15.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	559	1.1	33.	2.	0.	98.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
4	37	2.1	58.	0.	0.	96.	4.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	137	1.3	40.	95.	0.	5.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
5	128	1.6	47.	9.	0.	86.	5.	0.	0.	0.	0.	0.	0.	91.	0.	0.	0.	4.	5.	0.
	628	1.1	46.	6.	0.	89.	0.	0.	6.	0.	0.	0.	0.	95.	0.	0.	0.	5.	0.	0.
6	20	1.5	79.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	520	0.8	59.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.	45.	0.	0.	55.	0.	0.	0.
7	23	2.6	79.	4.	0.	96.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	523	1.9	50.	2.	0.	98.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
8	103	2.9	79.	0.	0.	90.	10.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	603	1.0	32.	0.	0.	41.	0.	58.	0.	0.	0.	0.	0.	0.	0.	0.	99.	0.	0.	0.
9	146	2.1	69.	4.	0.	90.	6.	0.	0.	0.	0.	0.	0.	99.	0.	0.	0.	0.	0.	1.
	646	1.2	47.	1.	0.	93.	0.	0.	7.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
10	136	2.2	52.	3.	0.	97.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	636	1.6	44.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
11	145	1.6	69.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	645	0.6	35.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
MEAN ORIGINAL DESIGN		2.2	66.	2.	0.	83.	4.	1.	9.	0.	0.	0.	0.	98.	0.	0.	0.	0.	1.	0.
MEAN REDESIGN		1.2	43.	10.	0.	82.	0.	6.	2.	0.	0.	0.	0.	80.	0.	0.	20.	0.	0.	0.

REPS PHASE II KEY DATA BASE PARAMETER: ELEMENTARY SCHOOLS
SECONDARY SYSTEM

04-JAN-83
PAGE 4

P.A. NO.	BLOG NO.	SYSTEM ID		T-STAT SET PT.				COOL	DAY	NIGHT	NIGHT	DEAD	HEAT TO RA	TEMP CTRL	EXHAUST AIR HEAT RECOVERY VENT EFF	SUPPLY CFM/SF PER. INT.	CFM PER RHP	OUTSIDE AIR			ECOD TYPE		
		INT	PER	HEAT	HEAT	HEAT	BAND											%	CFM	CFM/PER			
1	77	1	1	78.	68.	58.	YES	0.	25.			0.	25.		0.	0.	0.94	0.94	624.	15.	8721.	11.	75.
	577	1	1	78.	68.	58.	YES	0.	50.	NO		0.	50.	NO	0.	0.	0.76	0.56	791.	11.	5720.	7.	ENTH
2	13	0	3	75.	75.	60.	YES	0.	0.			0.	0.		31.	79.	1.43	0.00	1967.	29.	26748.	27.	72.
	513	15	15	78.	75.	60.	YES	3.	0.			3.	0.		0.	0.	1.43	1.26	2244.	19.	15029.	15.	76.
3	59	0	2	78.	72.	60.	YES	9.	80.			9.	80.		0.	0.	1.16	0.00	1100.	20.	3780.	15.	55.
	559	0	5	78.	72.	50.	YES	8.	60.	NO		8.	60.	NO	0.	0.	1.00	0.00	1120.	12.	2200.	8.	ENTH
4	37	0	15	75.	70.	60.	YES	5.	60.			5.	60.		100.	30.	1.19	0.00	3827.	15.	7462.	11.	
	137	0	0	0.	75.	75.	YES	0.	0.			0.	0.		0.	0.	0.00	0.00	0.	0.	0.	0.	
5	128	7	5	76.	72.	65.	YES	0.	30.	NO		0.	30.	NO	21.	65.	1.22	2.13	940.	29.	23405.	27.	55.
	628	7	5	78.	70.	60.	YES	8.	30.	NO		8.	30.	NO	0.	0.	0.82	0.59	1175.	21.	9209.	11.	55.
6	20	0	14	78.	70.	70.	YES	0.	0.			0.	0.		0.	0.	0.31	0.00	4881.	36.	2074.	6.	
	520	0	15	78.	70.	55.	YES	0.	0.			0.	0.		0.	0.	0.57	0.00	7381.	22.	2225.	6.	57.
7	23	0	4	78.	70.	50.	YES	0.	50.			0.	50.		0.	0.	0.91	0.00	1167.	10.	7036.	9.	ENTH
	523	0	4	78.	68.	60.	YES	10.	50.			10.	50.		0.	0.	1.41	0.00	2535.	4.	4388.	5.	ENTH
8	103	0	2	78.	70.	0.	NO	0.	20.			0.	20.		0.	0.	1.29	0.00	1502.	10.	6121.	8.	59.
	603	0	5	78.	70.	0.	NO	8.	0.	NO		8.	0.	NO	0.	0.	1.18	0.00	1874.	10.	5452.	7.	ENTH
9	146	3	3	78.	75.	0.	NO	0.	20.			0.	20.		0.	0.	1.75	1.60	2656.	10.	9402.	10.	75.
	646	0	3	75.	75.	0.	NO	0.	20.			0.	20.		0.	0.	1.65	0.00	4021.	12.	11229.	13.	75.
10	136	3	3	75.	75.	0.	NO	0.	0.			0.	0.		0.	0.	2.01	1.39	1441.	19.	13860.	19.	
	636	0	0	70.	70.	0.	NO	0.	0.			0.	0.		0.	0.	0.00	0.00	0.	0.	0.	0.	
11	145	0	3	78.	72.	0.	NO	0.	35.			0.	35.		0.	0.	0.98	0.00	787.	23.	9596.	16.	60.
	645	0	3	78.	68.	0.	NO	0.	35.			0.	35.		0.	0.	0.81	0.00	856.	10.	3468.	6.	60.
MEAN ORIGINAL DESIGN				77.	72.	38.			7.	40.					14.	16.	1.20	1.51	1899.	20.	10746.	14.	
MEAN REDESIGN				70.	71.	38.			7.	41.					0.	0.	0.87	0.80	2000.	11.	5356.	7.	

REPS PHASE II KEY DATA BASE PARAMETER: ELEMENTARY SCHOOLS
PRIMARY SYSTEM

06-JAN-83
PAGE 5

P.A. NO.	BLDG. NO.	CUTLER COOLING COP	HEATING EFF.	HEAT RECOVERY	HEAT PUMP TYPE	HP HEATING COP	COOLING FUEL TYPE	HOT WATER STORAGE (BTU/BTU CAP)	AUX. KW COOLING VAR. CONST	AUX. KW HEATING VAR. CONST	S.F. PER TON	HEATING BTU PER SF		
1	71 577	2.9 2.9	0.8 0.8			0.0 0.0	E E	0. 0.	0. 0.	7. 5.	280. 394.	86. 47.		
2	13 513	3.2 2.6	0.8 0.0		11	0.0 3.1	E E	0. 0.	11. 20.	19. 0.	6. 0.	310. 0.	69. 0.	
3	59 559	3.4 2.1	1.0 1.0	YES		0.0 0.0	E E	0. 0.	0. 0.	0. 0.	339. 433.	2. 14.		
4	37 137	4.1 0.0	0.0 1.0		11	3.4 0.0	E E	0. 0.	0. 0.	19. 0.	0. 0.	0. 0.	0. 29.	
5	128 628	5.0 5.0	0.8 0.8			0.0 0.0	E E	0. 0.	0. 15.	45. 10.	5. 2.	368. 559.	51. 40.	
6	70 520	2.0 2.3	1.0 1.0			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	510. 451.	23. 0.		
7	23 523	2.8 4.2	1.0 0.0	YES		0.0 0.0	E E	0. 0.	0. 12.	0. 12.	0. 0.	438. 331.	53. 0.	
8	103 603	3.3 3.9	0.8 0.8			0.0 0.0	E E	0. 0.	10. 5.	23. 10.	0. 3.	317. 509.	32. 28.	
9	146 646	2.7 2.6	1.0 1.0			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	770. 418.	27. 2.		
10	136 636	1.3 0.0	1.0 1.0			0.0 0.0	E E	0. 0.	0. 0.	39. 0.	0. 0.	215. 0.	21. 3.	
11	145 645	3.0 3.5	0.8 0.0	YES		0.0 0.0	E E	0. 498000.	4. 10.	0. 11.	0. 0.	287. 1690.	29. 0.	
MEAN ORIGINAL DESIGN		3.1	0.9	1		3.4		0.	2.	13.	2.	1.	333.	36.
MEAN REDESIGN		2.6	0.9	2		3.1		498000.	6.	4.	1.	1.	598.	15.

P.A. NO.	BLDG NO.	FLOOR AREA		ORIENT. DFG. FRN NORTH	MAJOR ORIENT.	WINTER INF. (ACH)	WALL BELOW GRADE	U-VALUES				BLDG MASS (LB/SF)			BLDG COLOR	
		GROSS	NET					WALL	ROOF	GLASS	COMPOSITE	WALL	ROOF	FLOOR	WALL	ROOF
12	41	127750.	120678.	334	N-S	0.50	0.	0.14	0.09	0.99	0.13	111.7	10.0	50.0	D	P
	541	119785.	114358.	334	E-W	0.15	71.	0.08	0.05	0.50	0.10	80.0	6.5	40.0	L	L
13	3	23294.	20059.	10		1.00	0.	0.12	0.05	1.05	0.12	101.5	14.0	49.5	L	D
	503	23500.	20004.	10		0.75	10.	0.10	0.12	0.60	0.14	106.4	50.0	49.5	L	D
14	62	45840.	43721.	0		0.50	0.	0.12	0.08	1.10	0.11	66.0	27.0	50.0	M	M
	562	47200.	46080.	0		0.50	19.	0.08	0.06	0.55	0.09	76.7	27.0	50.0	M	M
15	36	75490.	63442.	0	N-S	0.20	20.	0.08	0.13	1.10	0.10	11.9	10.0	38.0	L	L
	536	73000.	58750.	0	E-W	0.39	14.	0.06	0.04	0.56	0.11	8.7	10.0	38.0	L	L
16	2	285347.	269446.	346		0.70	17.	0.10	0.11	0.61	0.13	49.9	10.6	45.4	M	M
	502	266981.	258851.	35		0.50	15.	0.10	0.11	0.61	0.14	49.8	10.6	45.4	M	M
17	120	11890.	10537.	45	E-W	0.80	0.	0.71	0.14	1.10	0.37	94.5	35.0	50.0	M	D
	620	11910.	10310.	45	E-W	0.40	0.	0.08	0.05	0.56	0.11	103.0	123.0	50.0	M	M
18	112	51336.	49636.	0	N-S	0.40	0.	0.26	0.12	1.10	0.18	80.0	20.0	50.0	M	M
	612	51336.	49636.	0		0.40	25.	0.10	0.07	0.56	0.09	66.0	20.0	50.0	M	M
19	142	187746.	162257.	0	E-W	0.40	0.	0.10	0.07	0.96	0.11	40.0	52.0	53.0	M	D
	642	175649.	148518.	0		0.40	0.	0.07	0.05	0.56	0.08	68.0	75.0	53.0	L	L
20	97	133454.	113070.	11	E-W	0.20	2.	0.25	0.25	1.10	0.26	71.4	40.0	77.2	L	M
	597	136000.	112500.	11	E-W	0.20	45.	0.07	0.19	0.00	0.17	94.0	20.0	77.2	L	L
21	75	244000.	215550.	0	E-W	0.05	16.	0.07	0.05	0.39	0.10	85.4	219.0	105.0	M	M
	575	254794.	230478.	0	E-W	0.04	28.	0.07	0.04	0.35	0.09	85.4	219.0	105.0	M	M
22	152	10560.	10511.	0	N-S	0.70	0.	0.17	0.05	1.10	0.13	24.0	10.8	47.0	M	L
	652	14470.	11490.	0	N-S	0.21	56.	0.14	0.09	0.61	0.12	60.0	30.0	47.0	L	L

MEAN ORIGINAL DESIGN 108787. 98076. 68. 0.50 5. 0.19 0.10 0.96 0.16 66.9 40.8 55.9

MEAN REDESIGN 106784. 96452. 40. 0.36 26. 0.09 0.08 0.50 0.11 72.5 53.7 55.0

P.A. NO.	R/DG NO.	PLUG GLASS AREAS				SKYLIGHT AREA (%ROOF)	GLASS SHADE COEFFICIENT				EXT SHADE	PROCESS LOADS			
		SQ FT	EAST	SOUTH	NORTH		SOUTH	NORTH	EAST	WEST		GENERAL KW/SF	BTUH/SF	SPECIAL KW/SF	BTUH/SF
12	41	3394.	8.	17.	27.	0.	0.85	0.85	0.85	0.85		0.000	0.0	0.003	4.2
	541	7780.	72.	71.	25.	0.	0.15	0.15	0.15	0.15	YES	0.000	0.0	0.004	4.5
13	3	1046.	8.	41.	14.	1.	0.95	0.95	0.95	0.95		0.000	0.0	0.001	28.4
	503	778.	7.	21.	59.	1.	0.88	0.88	0.88	0.88	YES	0.000	0.0	0.001	25.5
14	62	972.	6.	16.	42.	0.	0.90	0.90	0.90	0.90		0.000	0.0	0.000	0.0
	562	1498.	10.	54.	21.	0.	0.90	0.90	0.90	0.90	YES	0.000	0.0	0.000	0.0
15	36	2641.	16.	20.	28.	0.	0.95	0.95	0.95	0.95	YES	0.001	0.0	0.001	5.3
	536	10376.	28.	64.	12.	0.	0.35	0.95	0.50	0.95	YES	0.000	0.0	0.001	0.0
16	2	12460.	18.	34.	15.	0.	0.56	0.56	0.56	0.56		0.000	0.0	0.006	0.0
	502	14774.	20.	47.	36.	0.	0.56	0.56	0.56	0.56	YES	0.000	0.0	0.007	0.0
17	120	1358.	21.	41.	27.	0.	0.80	0.80	0.80	0.80	YES	0.000	0.0	0.000	0.0
	620	1422.	21.	41.	27.	6.	0.80	0.80	0.80	0.80	YES	0.000	0.0	0.000	0.0
18	112	1313.	6.	19.	24.	0.	0.70	0.70	0.70	0.70		0.000	0.0	0.004	0.0
	612	944.	6.	31.	15.	1.	0.56	0.56	0.56	0.56	YES	0.000	0.0	0.004	0.0
19	142	8488.	9.	36.	21.	0.	0.74	0.74	0.74	0.74		0.000	0.0	0.002	4.3
	642	3863.	3.	23.	77.	0.	0.83	0.83	0.83	0.83	YES	0.000	0.0	0.002	4.6
20	97	572.	2.	9.	66.	0.	1.00	1.00	1.00	1.00	YES	0.000	0.0	0.000	15.0
	597	1.	0.	0.	0.	0.	0.00	0.00	0.00	0.00		0.000	0.0	0.000	14.7
21	75	13959.	21.	46.	35.	5.	0.20	0.30	0.17	0.17		0.000	0.0	0.000	0.0
	575	8208.	17.	60.	27.	6.	0.17	0.30	0.17	0.17	YES	0.000	0.0	0.000	0.0
22	152	420.	4.	22.	17.	0.	1.00	1.00	1.00	1.00		0.000	0.0	0.000	0.0
	652	698.	28.	19.	30.	0.	1.00	1.00	1.00	1.00	YES	0.000	0.0	0.000	0.0
MEAN ORIGINAL DESIGN		4302.	11.	27.	31.	1.	0.79	0.80	0.78	0.78		0.000	0.0	0.001	5.2
MEAN REDESIGN		4577.	19.	39.	30.	1.	0.62	0.69	0.61	0.66		0.000	0.0	0.002	4.5

FEPS PHASE II KEY DATA BASE PARAMETER: SECONDARY SCHOOLS
LIGHTING SYSTEM

04-JAN-83
PAGE 3

P.A. NO.	BLDG NO.	WALLS PER S.F.	ILLUM. LEVEL	LAMP TYPE (PERCENT TOTAL FLOOR AREA)								CONTROL TYPE (% TOTAL FLOOR AREA)							
				INC	TH	F	HG	MH	HPS	LPS	U	SKR	SK	LV	CPTR	PH	DIM	TC	O
12	41	2.5	50.	13.	0.	87.	0.	1.	0.	0.	0.	1.	73.	0.	0.	0.	1.	0.	25.
	541	1.4	33.	1.	0.	14.	0.	56.	29.	0.	0.	22.	17.	0.	0.	52.	0.	9.	0.
13	3	2.8	62.	12.	0.	88.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	503	0.9	35.	0.	0.	85.	0.	0.	0.	0.	15.	0.	100.	0.	0.	0.	0.	0.	0.
14	62	2.1	64.	0.	0.	82.	18.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	562	1.4	47.	0.	0.	84.	0.	0.	16.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
15	36	2.2	91.	10.	0.	90.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	536	0.7	41.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.	0.	0.	69.	0.	31.	0.
16	2	1.8	51.	6.	0.	84.	8.	0.	0.	0.	0.	10.	17.	56.	0.	14.	1.	0.	0.
	502	1.7	49.	2.	0.	86.	11.	0.	0.	0.	0.	4.	12.	71.	0.	11.	1.	0.	0.
17	120	2.8	75.	0.	0.	100.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	620	1.6	53.	0.	0.	100.	0.	0.	0.	0.	0.	0.	32.	0.	0.	68.	0.	0.	0.
18	112	2.2	70.	1.	1.	77.	20.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	612	1.3	42.	2.	0.	81.	0.	17.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
19	142	2.5	52.	8.	0.	81.	11.	0.	0.	0.	0.	0.	94.	0.	0.	0.	6.	0.	0.
	642	2.0	50.	3.	7.	82.	0.	0.	7.	0.	0.	0.	93.	0.	0.	0.	7.	0.	0.
20	97	3.2	54.	10.	0.	66.	24.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	597	0.9	29.	0.	0.	92.	8.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
21	75	2.0	51.	29.	2.	68.	1.	0.	0.	0.	0.	1.	77.	0.	0.	0.	5.	17.	0.
	575	0.9	33.	31.	2.	62.	6.	0.	0.	0.	0.	4.	79.	0.	0.	0.	3.	14.	0.
22	152	3.1	90.	0.	0.	100.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	652	1.5	64.	0.	0.	100.	0.	0.	0.	0.	0.	0.	25.	0.	0.	75.	0.	0.	0.
MEAN ORIGINAL DESIGN		2.5	64.	8.	0.	84.	8.	0.	0.	0.	0.	1.	87.	5.	0.	1.	1.	2.	2.
MEAN REDESIGN		1.3	43.	4.	1.	90.	2.	7.	5.	0.	1.	3.	60.	6.	0.	25.	1.	5.	0.

REPS PHASE II KEY DATA BASE PARAMETER: SECONDARY SCHOOLS
SECONDARY SYSTEM

04-JAN-83
PAGE 4

P.A. NO.	BLDG NO.	SYSTEM ID		T-STAI		SET PT.		COOL.	DAY	NIGHT	NIGHT	DEAD	HEAT	TEMP	EXHAUST AIR	HEAT RECOVERY	CFM/SE	PER	OUTSIDE AIR		FLOOR
		INI	PER	HEAT	HEAT	HEAT	HEAT												%	CFM	CFM/PER
12	41 541	3 7	3 7	80. 78.	70. 68.	0. 40.	YES YES	10. 10.	0. 0.	NO	0. 0.	0. 0.	0. 53.	0. 64.	1.34 0.75	1.24 1.16	925. 1058.	33. 41.	52281. 39009.	44. 33.	
13	3 503	0 0	2 3	75. 78.	72. 69.	62. 60.	YES YES	0. 0.	0. 0.		0. 0.	0. 0.	0. 0.	0. 0.	1.26 1.06	0.00 0.00	1012. 3652.	39. 23.	9987. 4900.	41. 32.	
14	62 542	0 13	2 13	78. 80.	72. 68.	60. 60.	YES YES	0. 0.	20. 0.	NO	0. 0.	0. 0.	0. 43.	0. 67.	1.17 1.25	0.00 1.37	1378. 3040.	13. 18.	6822. 11051.	18. 29.	70.
15	36 536	4 5	3 5	74. 78.	70. 72.	60. 40.	YES YES	0. 6.	70. 70.	NO NO	0. 0.	0. 0.	62. 61.	65. 65.	1.16 0.93	0.91 1.14	628. 1053.	22. 18.	16175. 10335.	19. 12.	57.
16	2 502	7 7	5 5	75. 75.	70. 70.	55. 55.	YES YES	0. 0.	30. 30.	NO NO	0. 0.	0. 0.	24. 0.	68. 0.	1.27 0.98	0.93 0.67	889. 842.	33. 24.	103391. 51277.	69. 34.	
17	120 620	3 0	3 3	75. 75.	75. 75.	0. 0.	NO NO	0. 6.	0. 0.		0. 0.	0. 0.	0. 0.	0. 0.	1.28 1.29	1.00 0.00	1912. 1473.	25. 25.	3298. 3115.	15. 15.	66. 70.
18	112 612	0 0	15 15	75. 78.	70. 70.	60. 60.	YES YES	4. 7.	0. 0.		0. 0.	0. 0.	0. 0.	0. 0.	1.03 0.73	0.00 0.00	3800. 3621.	10. 17.	5211. 6191.	10. 12.	
19	142 642	0 5	10 7	75. 78.	70. 70.	0. 0.	NO NO	0. 0.	0. 0.	NO	0. 0.	0. 0.	0. 0.	0. 0.	1.85 1.19	0.00 0.85	1672. 1670.	34. 45.	101654. 78902.	56. 44.	65. ENTH
20	97 597	15 15	3 15	75. 78.	75. 68.	75. 68.	YES YES	0. 0.	0. 0.		0. 0.	0. 0.	0. 100.	0. 85.	1.47 0.92	1.74 1.09	2248. 1583.	8. 51.	13839. 58064.	12. 48.	ENTH
21	75 575	4 4	5 5	78. 78.	68. 68.	60. 60.	YES YES	0. 0.	0. 0.	NO NO	0. 0.	0. 0.	100. 100.	50. 50.	1.02 0.99	0.63 0.71	602. 286.	10. 10.	16621. 18772.	17. 17.	60. 60.
22	152 652	0 0	3 5	75. 75.	72. 72.	72. 72.	YES YES	0. 4.	0. 30.	NO	0. 0.	0. 0.	0. 100.	0. 63.	1.86 1.07	0.00 0.00	1885. 2374.	5. 20.	980. 3086.	2. 7.	ENTH
MEAN ORIGINAL DESIGN				76.	71.	46.		7.	40.				17.	17.	1.34	1.08	1541.	21.	30023.	28.	
MEAN REDESIGN				77.	70.	47.		7.	43.				42.	36.	1.01	1.00	1878.	27.	25900.	26.	

REPS PHASE II KEY DATA PAGE PARAMETERS: SECONDARY SCHOOLS
PRIMARY SYSTEM

06-JAN-83
PAGE 5

P.A. NO.	BLDG. NO.	CHILLER COOLING COP	HEATING EFF.	HEAT RECOVERY	HEAT PUMP TYPE	HP HEATING COP	COOLING FUEL TYPE	HOT WATER STORAGE (RTU/PTH CAP)	AUX. KW COOLING VAR.	AUX. KW CONST	AUX. KW HEATING VAR.	AUX. KW CONST	S.F. PER TON	HEATING BTU PER SF
12	41 541	3.5 3.5	0.8 0.8			0.0 0.0	E E	0. 0.	42. 28.	0. 0.	15. 9.	0. 0.	295. 519.	64. 23.
13	3 503	3.0 2.7	0.8 0.8			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 1.	0. 1.	256. 338.	82. 58.
14	62 562	3.3 3.4	1.0 1.0	YES		0.0 0.0	E E	0. 0.	0. 5.	0. 7.	0. 5.	0. 0.	256. 447.	44. 20.
15	36 536	3.0 4.5	0.8 0.8			0.0 0.0	E E	0. 0.	5. 11.	0. 0.	4. 4.	0. 0.	299. 556.	37. 16.
16	2 502	4.0 4.0	0.0 0.0	YES YES		0.0 0.0	E E	1400000. 1400000.	42. 45.	60. 105.	0. 0.	0. 0.	254. 190.	0. 0.
17	120 620	2.1 3.5	0.7 0.7			0.0 0.0	E E	0. 0.	0. 2.	0. 0.	0. 0.	0. 0.	295. 327.	71. 70.
18	112 612	2.5 2.7	1.0 1.0		11 11	3.0 2.9	E E	0. 7.	9. 7.	25. 20.	0. 0.	0. 0.	0. 0.	15. 7.
19	142 642	4.7 4.3	0.8 0.8			0.0 0.0	E E	0. 0.	0. 0.	124. 89.	19. 11.	0. 0.	206. 281.	49. 45.
20	97 577	2.8 1.8	0.8 0.0		11 11	2.4 4.0	E E	0. 16600000.	176. 16.	6. 12.	0. 0.	0. 0.	533. 0.	26. 0.
21	75 575	1.0 4.0	1.0 1.0			0.0 0.0	F E	0. 0.	41. 30.	29. 25.	12. 12.	0. 0.	579. 682.	47. 43.
22	152 652	2.3 2.6	1.0 1.0			0.0 0.0	E E	0. 0.	0. 2.	9. 5.	0. 0.	0. 0.	255. 463.	41. 7.
MEAN ORIGINAL DESIGN		2.9	0.9	1		2.6		466667.	29.	23.	4.	0.	323.	44.
MEAN PPDESIGN		3.3	0.9	2		3.5		*****	13.	24.	4.	0.	451.	26.

Station	Time	Temp	Wind	Dir	Bar	Hum	Cloud	Vis	Remarks
1	0000	50.0	10	090	30.0	75	0	10	
2	0100	49.5	10	090	30.0	75	0	10	
3	0200	49.0	10	090	30.0	75	0	10	
4	0300	48.5	10	090	30.0	75	0	10	
5	0400	48.0	10	090	30.0	75	0	10	
6	0500	47.5	10	090	30.0	75	0	10	
7	0600	47.0	10	090	30.0	75	0	10	
8	0700	46.5	10	090	30.0	75	0	10	
9	0800	46.0	10	090	30.0	75	0	10	
10	0900	45.5	10	090	30.0	75	0	10	
11	1000	45.0	10	090	30.0	75	0	10	
12	1100	44.5	10	090	30.0	75	0	10	
13	1200	44.0	10	090	30.0	75	0	10	
14	1300	43.5	10	090	30.0	75	0	10	
15	1400	43.0	10	090	30.0	75	0	10	
16	1500	42.5	10	090	30.0	75	0	10	
17	1600	42.0	10	090	30.0	75	0	10	
18	1700	41.5	10	090	30.0	75	0	10	
19	1800	41.0	10	090	30.0	75	0	10	
20	1900	40.5	10	090	30.0	75	0	10	
21	2000	40.0	10	090	30.0	75	0	10	
22	2100	39.5	10	090	30.0	75	0	10	
23	2200	39.0	10	090	30.0	75	0	10	
24	2300	38.5	10	090	30.0	75	0	10	
25	0000	38.0	10	090	30.0	75	0	10	
26	0100	37.5	10	090	30.0	75	0	10	
27	0200	37.0	10	090	30.0	75	0	10	
28	0300	36.5	10	090	30.0	75	0	10	
29	0400	36.0	10	090	30.0	75	0	10	
30	0500	35.5	10	090	30.0	75	0	10	
31	0600	35.0	10	090	30.0	75	0	10	
32	0700	34.5	10	090	30.0	75	0	10	
33	0800	34.0	10	090	30.0	75	0	10	
34	0900	33.5	10	090	30.0	75	0	10	
35	1000	33.0	10	090	30.0	75	0	10	
36	1100	32.5	10	090	30.0	75	0	10	
37	1200	32.0	10	090	30.0	75	0	10	
38	1300	31.5	10	090	30.0	75	0	10	
39	1400	31.0	10	090	30.0	75	0	10	
40	1500	30.5	10	090	30.0	75	0	10	
41	1600	30.0	10	090	30.0	75	0	10	
42	1700	29.5	10	090	30.0	75	0	10	
43	1800	29.0	10	090	30.0	75	0	10	
44	1900	28.5	10	090	30.0	75	0	10	
45	2000	28.0	10	090	30.0	75	0	10	
46	2100	27.5	10	090	30.0	75	0	10	
47	2200	27.0	10	090	30.0	75	0	10	
48	2300	26.5	10	090	30.0	75	0	10	
49	0000	26.0	10	090	30.0	75	0	10	
50	0100	25.5	10	090	30.0	75	0	10	
51	0200	25.0	10	090	30.0	75	0	10	
52	0300	24.5	10	090	30.0	75	0	10	
53	0400	24.0	10	090	30.0	75	0	10	
54	0500	23.5	10	090	30.0	75	0	10	
55	0600	23.0	10	090	30.0	75	0	10	
56	0700	22.5	10	090	30.0	75	0	10	
57	0800	22.0	10	090	30.0	75	0	10	
58	0900	21.5	10	090	30.0	75	0	10	
59	1000	21.0	10	090	30.0	75	0	10	
60	1100	20.5	10	090	30.0	75	0	10	
61	1200	20.0	10	090	30.0	75	0	10	
62	1300	19.5	10	090	30.0	75	0	10	
63	1400	19.0	10	090	30.0	75	0	10	
64	1500	18.5	10	090	30.0	75	0	10	
65	1600	18.0	10	090	30.0	75	0	10	
66	1700	17.5	10	090	30.0	75	0	10	
67	1800	17.0	10	090	30.0	75	0	10	
68	1900	16.5	10	090	30.0	75	0	10	
69	2000	16.0	10	090	30.0	75	0	10	
70	2100	15.5	10	090	30.0	75	0	10	
71	2200	15.0	10	090	30.0	75	0	10	
72	2300	14.5	10	090	30.0	75	0	10	
73	0000	14.0	10	090	30.0	75	0	10	
74	0100	13.5	10	090	30.0	75	0	10	
75	0200	13.0	10	090	30.0	75	0	10	
76	0300	12.5	10	090	30.0	75	0	10	
77	0400	12.0	10	090	30.0	75	0	10	
78	0500	11.5	10	090	30.0	75	0	10	
79	0600	11.0	10	090	30.0	75	0	10	
80	0700	10.5	10	090	30.0	75	0	10	
81	0800	10.0	10	090	30.0	75	0	10	
82	0900	9.5	10	090	30.0	75	0	10	
83	1000	9.0	10	090	30.0	75	0	10	
84	1100	8.5	10	090	30.0	75	0	10	
85	1200	8.0	10	090	30.0	75	0	10	
86	1300	7.5	10	090	30.0	75	0	10	
87	1400	7.0	10	090	30.0	75	0	10	
88	1500	6.5	10	090	30.0	75	0	10	
89	1600	6.0	10	090	30.0	75	0	10	
90	1700	5.5	10	090	30.0	75	0	10	
91	1800	5.0	10	090	30.0	75	0	10	
92	1900	4.5	10	090	30.0	75	0	10	
93	2000	4.0	10	090	30.0	75	0	10	
94	2100	3.5	10	090	30.0	75	0	10	
95	2200	3.0	10	090	30.0	75	0	10	
96	2300	2.5	10	090	30.0	75	0	10	
97	0000	2.0	10	090	30.0	75	0	10	
98	0100	1.5	10	090	30.0	75	0	10	
99	0200	1.0	10	090	30.0	75	0	10	
100	0300	0.5	10	090	30.0	75	0	10	

10/10/00

10/10/00

SUMMARY OF SECTION CONTENTS

6. Assembly and Warehouses

a. Building Type Analysis

6.1 Storage Buildings

6.1.1 Building Characteristics

- o Physical Description
- o Space Mix
- o Standard Building Operating Conditions

6.1.2 Energy End Uses

6.1.3 Redesign Strategies

6.2 Energy End Uses

6.2.1 Building Characteristics

- o Physical Description
- o Space Mix
- o Standard Building Operating Conditions
- o Sample

6.2.2 Energy End Uses

6.2.3 Redesign Strategies

b. Key Energy Parameters - Graphic Presentations

c. Key Energy Parameters - Extractions from Computer Stored Data

A. Building Type Analysis: Storage and Assembly Buildings

The following section presents a summary of the major conclusions from the analyses conducted for Storage and Assembly Buildings during the course of the BEPS research. Included in this presentation are brief synopses of building characteristics for warehouses and assembly buildings, such as their physical description, operating profiles, space mix and sampling issues. Predominant energy end uses and their relationship to key energy strategies are also discussed.

6.1 Storage Buildings

6.1.1 Building Characteristics. Here we briefly summarize the energy-related characteristics of sample storage buildings that were included in the analysis.

Physical Description. Warehouses are without doubt the most utilitarian building type of the sixteen building types included in the BEPS building classification. Typically, they are one or two story shells which are usually located in industrial parks.

The building assembly is, in most cases, made of pre-engineered light weight metal components with a rectangular shell configuration. Few deviations from this norm are observed as economic factors are predominant in the design of these buildings. Minimization of first costs is a very strong drive force and results in simple site plans with minimal landscaping.

Space Mix. Warehouses accommodate a wide variety of uses ranging from straight warehousing to distribution terminals or even light industrial processes. Most of the warehouses in the redesign sample were confined to storage functions with relatively small areas devoted to office support functions (see Figure 6.10).

The nature of the product stored can have a striking impact on the range of conservation strategies applicable to a given warehousing situation. For instance, the storage of perishable goods at low temperatures presents the designer with an entirely different set of issues than the storage of

heavy duty industrial components. In the first case, control of thermal transmission and use of process cooling heat recovery would be the most likely concerns, whereas in the second instance, space conditioning might not even be required.

Standard Building Operating Conditions. Compared to other building types, warehouses are one of the least intensive energy users. As shown in Figure 6.11, "Storage Standard Operating Profiles", the warehouse sample's HVAC equipment was reported to be operating 40 hours per week; the result of a predominantly daytime occupancy pattern (7 a.m. to 5 p.m.). This occupancy profile also drives the HVAC equipment usage profile, as well as the lighting and the service hot water profiles. Of course, cold storage warehouses would require conditioning 24 hours a day, seven days a week.

Building Sample. While the warehouse sample of 10 buildings is not very large, its geographical distribution represents most climate conditions with little duplication of sites (see Figure 6.12). However, hot and humid conditions are not represented, and conclusions reached regarding this building type should not be extended to the hot and humid climates without additional information and analysis.

6.1.2 Energy End Uses. Along with elementary schools and multifamily low rise buildings, warehouses are among the least energy intensive of the redesign building types. Annual energy consumption for the original buildings was in the 62,000 Btu/sq ft/yr range. The redesigns were in the 28,000 Btu/sq ft/yr range; the lowest of any building type.

Most of this energy use is to satisfy heating loads. (See Figure 6.13 "Warehouses Design Energy Consumption Levels Per Building" for a case-by-case breakdown of energy end uses). Heating energy represents, on the average, 66% to 75% of the total energy consumption for the redesigns and original buildings, respectively. This is not surprising given the very low levels of internal loads found in warehouses and the predominance of infiltration and conduction loads.

Besides heating energy, lighting energy is the next most significant end use. In spite of the low illumination levels required in warehouses, lighting represents 15% to 20% of the total energy use in original and redesigned buildings, respectively.

On the average, the redesigns were 13% more energy efficient than in their ASHRAE standard configuration 90-75. However, the requirements of 37,000 Btu/sq ft/yr compared to 62,000 Btu/sq ft/yr for the original buildings.

6.1.3 Redesign Strategies. Warehouses can be viewed as a prototypical "skin-load" dominated building. As such, conservation strategies and energy consumption levels are to a large extent dictated by climate considerations. In cold areas more emphasis should be placed on reducing conduction and infiltration losses. Especially in active warehouses, infiltration can be the predominant energy load. In hot/mild climates, more attention should be paid to ventilation and the reduction of solar loads on opaque and clear surfaces, especially on roofs. In mild climates, storage buildings can be left unconditioned during the intermediate and cooling seasons unless the stored products have critical temperature requirements.

Conduction. Redesign strategies aimed at reducing conduction gains and losses through the shell included upgrading the insulation levels of: walls, overhead doors, roofs and glass (see Figure 6.1). Reduction in glass area generally occurred where daylighting strategies were not employed. Infiltration measures included weatherstripping and air lock entries. Form changes (i.e., compaction, elongation on an east-west axis, self shading) did not play any significant role in the redesign process, given that most storage buildings in the sample were metal skinned, pre-fabricated shells and that any deviation from a rectangular format would not have been cost effective.

Solar Control. Solar control measures in the redesigns were confined to the re-orientation of the building on an east-west axis and/or the relocation of glass to the south (see Figure 6.2).

Lighting. Daylighting applications occurred as a significant redesign strategy, even though the required foot candle levels in warehouses is low. However, the building configuration lends itself very well to extensive skylighting. Note that daylighting benefits are in this case not as sizeable, since the type of task is amenable to the use of very efficient light sources.

As far as lighting sources, redesigns increased the use of H.I.D. lamps. The tendency was to use high pressure sodium in non-critical areas and to use mercury vapor in critical storage areas. Incandescent lamps were replaced where feasible (see Figure 6.3). Overall lighting conservation measures decreased lighting energy for the whole sample by 30%.

HVAC. From the standpoint of HVAC systems, few changes occurred in either primary or secondary systems (see Figure 6.6). The most relevant strategies were the following:

- o Use of de-stratification fans to remove hot air from the upper ceiling activity,
- o Timeclock controls,
- o Use of radiant heaters in non-conditioned areas (either gas or infrared),
- o Night setback temperature control,
- o In a few instances, return air from office spaces is used in warehouse cooling (see Figure 6.14).

As a result of redesign conservation measures, the construction cost of most projects in the sample increased. The average cost increase was approximately 5%; maximum and minimum increases were 15% And 0%, respectively.

6.2 Assembly Buildings

Within the BEPS research and publications, assembly buildings were treated in different ways at different points in time. The sample designs and energy analyses for both Phases 1 and 2 treated "Assembly Buildings" as a single, aggregated building type.

During the course of the research, it was concluded that there was enough diversity of energy-related factors for building subtypes within the "Assembly Building" type to treat the subtypes independently. Thus, the DOE BEPS NOPR of 1979 listed 3 subtypes of assembly building separately: Community Center; Gymnasium; and, Theatre/Auditorium. In large part, this subdivision of the category was made possible by the large number of assembly buildings in the Phase 1 sample. By itself, the Phase 2 sample was not large enough to permit such disaggregation.

Since our analysis in this report uses only the Phase 2 sample, we do not have enough sample buildings to treat the assembly building subtypes separately. Accordingly, our discussion covers

generic features of the overall building type, as well as some differentiating features among the subtypes.

6.2.1 Building Characteristics. The following paragraphs summarize the energy-related features of the assembly buildings in the sample.

Physical Description. Assembly buildings are normally one-story, or occasionally two-story, buildings which generally house activities requiring a large volume (See Figure 6.15 "Typical Redesign Building Configuration"). Fenestration is a nominally significant factor on energy use. Compared to small offices, for instance, assembly buildings have 40% less glass. However, they will have twice as much glass as warehouses.

Building configurations and floor plans in the assembly redesign sample vary widely. In most cases, the building shape results from the integration of high volume spaces with a series of smaller support areas.

Space Mix. The assembly building type actually encompasses a wide variety of sub-types which can include: convention centers dance halls; recreation centers; gymnasiums; theaters; etc. However, independent of the specific sub-type, peak occupancy densities are high compared to different building types. Major activities such as athletics, meetings, dancing, etc., can require from 36% to 81% of the total building area (See Figure 6.10). Other ancillary functions include circulation, lockers and showers, offices dining rooms and kitchens.

Standard Building Operating Conditions. Assembly buildings operate according to irregular but predictable schedules. Occupancy densities (which in most cases drive cooling equipment capacities) can experience sharp peaks, but, their occurrence is limited to less than 10% of the time.

On the average, lighting operates 58 hours per week at about 70% of the total installed capacity (for additional details, See Figure 6.16 "Standard Building Operating Profiles, Assembly Buildings").

Building Sample. The assembly building sample is limited to eleven (11) buildings which include: seven gymnasiums; two

auditoriums; a multi-purpose recreation center; and a theater. At first glance, this might seem an unrelated collection. However, these sample buildings share similar occupancy densities, fenestration requirements, building configuration and construction type.

The geographic distribution covers most basic climate types as can be observed in Figure 6.17. However, midwestern, coastal southwestern and coastal northeastern areas are left unrepresented in the sample.

6.2.2 Energy End Uses. Compared to other redesign building types, assembly buildings are average energy consumers. They are as energy intensive as clinics, stores or offices (See Progressive Architecture Article #1 "A Baseline for Energy Design" Figure 3). Original and redesign energy levels were 86,000 BTU/SQ.FT.YR and 48,000 BTU/SQ.FT.YR respectively, while the ASHRAE standard 90-75 configuration stood at 75,000 BTU/SQ.FT.YR (See Figure 6.18 "Assembly Design Energy Consumption Levels Per Building" for a case-by-case breakdown of energy end uses).

Of this total energy consumption, 43% was attributed to heating, and 13% to lighting. The redesigns were effective in reducing heating and lighting energy; however, other energy end uses showed only marginal reductions.

6.2.3 Redesign Strategies. As mentioned above, the two most significant end uses in assembly buildings are heating and lighting energy. Such a high percentage of heating energy is for the most part due to the following factors:

- o The shell area of assembly buildings is relatively high compared to the floor area enclosed.
- o Even though peak internal loads can be very substantial, their duration is restricted to a few hours per week. In all likelihood, most heating demands will arise from maintaining indoor conditions during unoccupied periods.

The following is a review of the major redesign strategies used as far as conduction, solar control, lighting and mechanical systems.

Conduction. Redesign strategies in assembly buildings, aimed at reducing shell conduction gains and losses, included upgrading wall and glass "U" values. Also, the use of berming was recurrent as a strategy aimed at improving the thermal resistance of walls (See Figure 6.3).

However, while glass U-values decreased, glass areas increased by 16% on the average (See Figure 6.4). This increase was the result of the application of passive solar strategies such as Trombe Walls in a few of the sample buildings. The combined impact of the measures described above was a 38% average decrease (i.e., improvement) in composite building U-value across the assembly sample. Additional conduction reduction strategies included the use of non-conditioned areas as buffer zones.

Most infiltration strategies were directed at reducing air leakage through entrances. Most prevalent were the use of air-lock entries and vestibules.

Solar Control. The most significant solar control strategy was the relocation of glass areas from the east and west exposures to the buildings south exposure (See Figure 6.4). In most cases this was the result of simply re-orienting the building from a north-south axis to an east-west axis. As buildings were re-oriented, exterior shading devices for solar gain control were added on the south; but interior shading coefficients were, on the average, left unchanged.

Lighting. Lighting energy was reduced by an average of 55% as a result of the redesign process. Most of this reduction stemmed from reducing installed lighting capacities and implementing more efficiently designed lighting systems. To a lesser extent, the replacement of lamp types was tried, but as for the most part, the original buildings were already making use of H.I.D. sources. See Figure 6.5 for additional details.

Daylighting in conjunction with continuous and two-step photocell controls was also quite prevalent.

HVAC. There were no major redesign changes observed in either primary or secondary HVAC systems except for a few instances where double bundle condensers were used (See Figure 6.6).

The most recurrent redesign strategy was the use of night temperature setback and time clock controls (See Figure 6.7). These two strategies can be quite effective, given both the high heating demands during non-occupied hours and the very predictable operation schedule of this building type.

Other strategies which were not predominant, but which were found in the redesign sample included:

- o Deadband temperature control
- o Reductions in conditioned square footage
- o Reductions in installed cooling capacities
- o Reduction in outside ventilation air
- o Heat recovery from shower drains for preheating domestic hot water

As a result of the redesign effort, the construction cost of most projects in the sample increased by an average of 4.8% and a maximum of 14% (See Figure 6.10). In only one instance did the first cost decrease.

KEY (1) ASSEMBLY
 [1] WAREHOUSE
 ↑ BUILDING I.D. NUMBER

FIGURE 6.1. Warehouse and Assembly

FIGURE 6.2. Frequency of Strategies - Warehouse and Assembly

FIGURE 6.3. Conduction - Warehouse and Assembly Buildings

FIGURE 6.4. Solar Control - Warehouse and Assembly Buildings

FIGURE 6.5. Lighting - Warehouse and Assembly Buildings

FIGURE 6.6. Primary and Secondary Systems - Warehouse and Assembly

FIGURE 6.7. HVAC Set Points - Warehouse and Assembly Buildings

FIGURE 6.8. Equipment Efficiency - Warehouse and Assembly Buildings

FIGURE 6.9A. Miscellaneous Energy Parameters

FIGURE 6.9B. Miscellaneous Energy Parameters

FIGURE 6.9C. Miscellaneous Energy Parameters

21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	BUILDING ID NUMBER
	1	12	17	7	2	6		2		6	68	34	87	90	31	54	82	99	85	62	STORAGE
											2	38					2				HAZARDOUS STORAGE
3	15	1		4	1	5	3			5	26	12	11	10	18	7	16	1	13	9	OFFICE
												3			40					29	ENCLOSED DOCK
	70	81																			DANCE FLOOR
			66		8	25	76	36	73												SEATING
	1		9	2						48											KITCHEN/DINING
49				46	28	8															ATHLETICS
				23																	MEETING
								13													STAGE
22	6			4	3	9									3						LOCKER/SHOWER
6	1		1	3	1	5	2	8	1	7	2	4			1						MECHANICAL
20	6	3		9	3	16	10	23	20	24		3			4						CIRCULATION
			3	7	2	3	2	1	3	10	2	1	2		1					2	TOILET
							15	6				5			2	39					OTHER

SPACE USE: PERCENT OF GROSS AREA

FIGURE 6.10. Space Use and Cost Change Warehouse and Assembly

FIGURE 6.11. Standard Building Operating Profiles - Warehouses

FIGURE 6.12. Geographical Distribution - Warehouse

FIGURE 6.13. Annual Energy End Uses - Warehouses

FIGURE 6.14. HVAC Redesign Example (Mechanical Schematic)

SOUTH ELEVATION

LONGITUDINAL SECTION

FIGURE 6.15. Typical Redesign Building Configuration Assembly

FIGURE 6.16. Standard Building Operating Profiles Assemblies

FIGURE 6.17. Geographical Distribution - Assembly Building

FIGURE 6.18. Annual Energy End Uses - Assembly Buildings

P.A. NO.	BLDG NO.	FLOOR AREA		ORIENT. DEG. FROM NORTH	MAJOR DIRECTION	WINTER INF. (ACH)	WALL BLDN GRADE	U-VALUES				BLDG MASS (LB/SE)			BLDG COLOR	
		GROSS	NET					WALL	ROOF	GLASS	COMPOSITE	WALL	ROOF	FLOOR	WALL	ROOF
11	7R 578	5016. 4679.	4207. 3964.	360 360	N-S E-W	0.28 0.17	18. 24.	0.10 0.07	0.08 0.05	0.69 0.58	0.15 0.10	83.0 83.0	7.0 40.0	45.0 45.0	D D	L L
12	65 565	21092. 21250.	20958. 20958.	0 0	E-W E-W	0.10 0.10	12. 11.	0.18 0.11	0.12 0.05	1.13 0.49	0.16 0.08	56.3 56.3	15.0 15.0	48.0 48.0	L L	L L
13	45 545	20300. 20200.	19800. 19800.	0 0		0.30 0.20	0. 7.	0.28 0.10	0.15 0.05	1.10 0.42	0.23 0.08	77.0 87.0	12.0 16.0	55.0 55.0	M D	M L
14	47 547	35256. 35498.	34726. 33792.	0 0	E-W E-W	0.15 0.15	6. 27.	0.13 0.08	0.09 0.09	0.94 0.60	0.13 0.12	52.1 48.8	10.0 5.0	48.0 48.0	M D	D D
15	31 531	34191. 35300.	31345. 32095.	350 0	N-S N-S	0.08 0.08	15. 32.	0.15 0.06	0.05 0.04	0.52 0.52	0.12 0.08	132.5 119.4	77.0 22.0	80.0 80.0	L L	M M
16	9R 598	8032. 8036.	7893. 6928.	0 0	E-W E-W	0.50 0.40	0. 21.	0.26 0.05	0.15 0.09	1.10 0.65	0.22 0.13	62.0 35.0	35.0 38.0	46.0 46.0	M D	D D
17	17 517	21696. 21805.	17900. 17455.	0 0	E-W E-W	0.50 0.25	0. 9.	0.11 0.06	0.07 0.06	1.10 0.90	0.09 0.07	47.3 46.1	10.0 10.0	47.0 47.0	L L	M M
18	135 635	3392. 3392.	2760. 2962.	32 32	N-S N-S	0.00 0.75	0. 0.	0.06 0.03	0.07 0.03	1.10 1.10	0.25 0.19	10.2 10.2	11.5 15.3	50.0 50.0	D D	D D
19	115 615	9942. 10037.	9536. 7737.	10 350	N-S E-W	0.47 0.23	0. 22.	0.11 0.08	0.15 0.07	1.13 1.13	0.17 0.13	5.7 100.0	3.5 70.0	50.7 50.7	M L	M L
20	101 601	7781. 7415.	6692. 6911.	355 355	N-S E-W	0.00 0.20	0. 76.	0.33 0.16	0.15 0.04	1.10 1.10	0.25 0.08	100.0 100.0	70.0 70.0	100.0 100.0	M L	M L
21	144 644	18400. 17200.	17300. 16200.	340 340		0.50 0.50	0. 5.	0.41 0.27	0.07 0.05	1.10 1.10	0.25 0.17	48.7 90.3	16.0 16.0	75.0 75.0	L L	D L
MEAN ORIGINAL DESIGN		16781.	15738.	132.		0.26	5.	0.19	0.10	1.00	0.18	61.3	24.3	58.6		
MEAN REDESIGN		16801.	15346.	131.		0.28	21.	0.10	0.06	0.78	0.11	70.6	28.8	58.6		

REPS PHASE II KEY DATA BASE PARAMETER ASSEMBLY
ENVELOPE

04-JAN-93
PAGE 2

P.A. NO.	BLDG NO.	BLDG GLASS AREAS				SKYLIGHT AREA (%ROOF)	GLASS SHADE COEFFICIENT				EXT SHADE	PROCESS LOADS			
		SQ FT	ELEV	%SOUTH	%NORTH		SOUTH	NORTH	EAST	WEST		GENERAL Kw/SF	BTUH/SF	SPECIAL Kw/SF	BTUH/SF
11	7H	452.	14.	8.	20.	3.	0.80	0.80	0.80	0.80		0.000	0.0	0.005	29.9
	57H	324.	11.	82.	18.	0.	0.80	0.80	0.00	0.00	YES	0.000	0.0	0.005	32.1
12	65	434.	3.	73.	0.	0.	0.50	0.00	0.00	0.50	YES	0.000	0.0	0.001	0.0
	565	126.	1.	100.	0.	0.	0.94	0.00	0.00	0.00	YES	0.000	0.0	0.001	0.0
13	45	430.	2.	74.	26.	0.	0.95	0.95	0.00	0.00	YES	0.000	0.0	0.000	0.0
	545	550.	3.	53.	0.	1.	0.82	0.00	0.80	0.00	YES	0.000	0.0	0.000	0.0
14	47	1537.	7.	90.	0.	0.	0.64	0.00	0.64	0.64		0.000	0.0	0.000	0.0
	547	2031.	17.	97.	0.	8.	0.97	0.00	0.85	0.00		0.000	0.0	0.000	0.0
15	31	2125.	11.	10.	51.	1.	0.90	0.90	0.90	0.90	YES	0.000	0.0	0.000	0.0
	531	2258.	13.	49.	0.	1.	0.90	0.00	0.90	0.90	YES	0.000	0.0	0.000	0.0
16	9H	160.	2.	75.	0.	0.	0.85	0.00	0.85	0.00	YES	0.000	0.0	0.000	0.0
	599	1313.	19.	97.	0.	0.	0.85	0.00	0.85	0.00		0.000	0.0	0.000	0.0
17	17	147.	1.	69.	22.	0.	1.00	1.00	0.00	1.00		0.000	0.0	0.001	0.0
	517	209.	2.	41.	53.	1.	1.00	1.00	0.00	1.00	YES	0.000	0.0	0.001	0.0
18	135	1050.	35.	27.	24.	0.	0.72	0.69	0.69	0.71	YES	0.000	0.0	0.012	0.0
	635	850.	35.	26.	24.	0.	0.69	0.69	0.69	0.69	YES	0.000	0.0	0.012	0.0
19	115	508.	6.	0.	1.	0.	0.00	0.90	0.90	0.90		0.000	0.0	0.000	0.0
	615	937.	14.	99.	1.	0.	0.90	0.90	0.00	0.00	YES	0.000	0.0	0.046	0.0
20	101	177.	2.	0.	44.	0.	0.00	1.00	1.00	1.00		0.000	0.0	0.001	0.0
	601	181.	12.	0.	65.	0.	0.00	0.95	0.00	0.95		0.000	0.0	0.001	0.0
21	144	864.	7.	23.	69.	0.	0.78	0.78	0.78	0.78	YES	0.000	0.0	0.002	19.7
	644	684.	6.	32.	58.	0.	0.78	0.78	0.78	0.78	YES	0.000	0.0	0.002	21.0
MEAN ORIGINAL DESIGN		717.	8.	41.	23.	0.	0.79	0.88	0.82	0.80		0.000	0.0	0.002	4.5
MEAN REDESIGN		860.	12.	61.	20.	1.	0.86	0.85	0.83	0.86		0.000	0.0	0.006	4.8

REPS PHASE II KEY DATA NAME PARAMETER: ASSEMBLY
LIGHTING SYSTEM

04-JAN-93
PAGE 3

P.A. NO.	BLDG NO.	WATTS		ILLUM. LEVEL	LAMP TYPE (PERCENT TOTAL FLOOR AREA)								CONTROL TYPE (% TOTAL FLOOR AREA)							
		PER S.F.			INC	TH	F	HC	MH	HPS	LPS	0	BKN	SA	LV	CPIR	PH	DIM	IC	0
11	78	2.9	31.	52.	0.	48.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	578	1.1	28.	2.	0.	91.	6.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
12	45	1.2	8.	100.	0.	0.	0.	0.	0.	0.	0.	0.	20.	0.	0.	0.	0.	80.	0.	0.
	565	1.1	7.	100.	0.	0.	0.	0.	0.	0.	0.	0.	18.	0.	0.	0.	0.	82.	0.	0.
13	45	6.9	45.	48.	0.	24.	23.	0.	0.	0.	0.	0.	0.	61.	0.	0.	1.	32.	0.	0.
	545	6.4	44.	52.	0.	27.	0.	15.	0.	0.	0.	0.	0.	62.	0.	0.	0.	32.	0.	0.
14	47	3.0	88.	3.	0.	24.	12.	62.	0.	0.	0.	0.	80.	19.	0.	0.	0.	0.	0.	0.
	547	1.1	65.	0.	0.	23.	3.	74.	0.	0.	0.	0.	82.	17.	0.	0.	0.	0.	0.	0.
15	31	1.6	44.	23.	0.	31.	32.	0.	0.	0.	0.	0.	9.	78.	0.	0.	0.	0.	0.	0.
	531	1.2	44.	3.	0.	46.	3.	32.	0.	0.	0.	0.	23.	29.	0.	0.	0.	32.	0.	0.
16	98	1.3	37.	0.	0.	45.	55.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	598	0.9	39.	0.	0.	45.	0.	0.	55.	0.	0.	0.	0.	11.	0.	0.	88.	0.	0.	0.
17	17	1.5	39.	2.	0.	50.	4.	43.	0.	0.	0.	0.	51.	23.	0.	0.	0.	23.	0.	2.
	517	1.3	38.	2.	0.	49.	5.	44.	0.	0.	0.	0.	0.	56.	0.	0.	44.	0.	0.	0.
18	135	3.0	28.	45.	0.	31.	25.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	635	2.1	30.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	100.
19	115	1.5	44.	0.	0.	34.	66.	0.	0.	0.	0.	0.	66.	34.	0.	0.	0.	0.	0.	0.
	615	0.9	44.	0.	0.	13.	0.	0.	80.	0.	0.	0.	0.	2.	0.	0.	91.	0.	0.	0.
20	101	1.6	39.	5.	0.	24.	71.	0.	0.	0.	0.	0.	71.	29.	0.	0.	0.	0.	0.	0.
	601	0.9	34.	0.	0.	35.	0.	65.	0.	0.	0.	0.	65.	35.	0.	0.	0.	0.	0.	0.
21	144	1.8	53.	30.	0.	70.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	644	1.7	57.	21.	0.	79.	0.	0.	0.	0.	0.	0.	0.	76.	0.	0.	24.	0.	0.	0.
MEAN ORIGINAL DESIGN		2.4	41.	28.	0.	35.	26.	10.	0.	0.	0.	0.	27.	59.	0.	0.	0.	12.	0.	0.
MEAN REDESIGN		1.7	39.	16.	0.	46.	2.	21.	12.	0.	0.	0.	17.	35.	0.	0.	22.	13.	0.	9.

HEPS PHASE II KEY DATA BASE PARAMETER: ASSEMBLY
SECONDARY SYSTEM

04-JAN-83
PAGE 4

P.A. NO.	PLDG NO.	SYSTEM ID		I-STAT SET PT.				HEAT TO RA	TEMP CEPL	EXHAUST AIR		SUPPLY		CFM PER RHP	OUTSIDE AIR			ECON TIME
		INT	PEP	COOL	DAY	NIGHT	NIGHT			HEAT RECOVERY	PERCENT	CFM/SF	PERCENT		%	CFM	CFM/PER	
11	78	7	7	55.	68.	65.	YES	0.	0.	0.	0.	1.38	0.23	3555.	25.	1227.	61.	
	578	7	7	55.	68.	55.	YES	0.	0.	0.	0.	1.11	0.10	2741.	10.	395.	20.	
12	65	0	3	78.	70.	70.	YES	8.	0.	0.	0.	1.85	0.00	1944.	22.	7584.	6.	60.
	565	0	3	78.	70.	60.	YES	8.	0.	0.	0.	1.67	0.00	1944.	2.	780.	1.	
13	45	2	2	75.	72.	65.	YES	0.	0.	0.	0.	1.78	0.80	1055.	15.	5000.	7.	62.
	545	3	3	78.	64.	58.	YES	10.	0.	0.	0.	1.30	0.14	1953.	15.	3779.	5.	
14	47	13	7	72.	72.	60.	YES	0.	0.	0.	0.	0.94	1.89	2538.	12.	3913.	20.	
	547	0	7	0.	68.	60.	YES	0.	0.	0.	0.	0.99	0.00	2558.	5.	1545.	2.	
15	31	0	7	0.	70.	65.	YES	0.	0.	0.	0.	1.24	0.00	2123.	8.	2770.	1.	
	531	0	7	70.	70.	65.	YES	0.	0.	0.	0.	1.20	0.00	2129.	1.	400.	0.	
16	48	7	7	0.	65.	65.	YES	0.	0.	0.	0.	1.80	0.80	5025.	15.	2111.	23.	
	598	7	7	65.	65.	45.	NO	0.	0.	100.	60.	0.10	0.69	1500.	100.	750.	8.	
17	17	0	3	78.	70.	55.	YES	0.	0.	0.	0.	1.66	0.00	2067.	18.	5323.	9.	60. ENTH
	517	0	2	78.	64.	55.	YES	0.	30.	0.	0.	0.98	0.00	1271.	15.	2564.	9.	
18	135	0	7	55.	72.	0.	NO	0.	0.	0.	0.	1.00	0.00	8324.	25.	687.	2.	
	635	0	7	55.	72.	0.	NO	5.	0.	0.	0.	0.93	0.00	8333.	0.	0.	0.	
19	115	3	7	55.	65.	65.	YES	0.	0.	0.	0.	0.84	1.12	5353.	0.	0.	0.	
	615	0	7	55.	55.	45.	YES	0.	0.	0.	0.	0.52	0.00	5004.	1.	23.	0.	
20	101	0	15	75.	70.	65.	YES	4.	0.	0.	0.	1.28	0.00	3254.	0.	0.	0.	ENTH
	601	0	15	78.	64.	60.	YES	10.	0.	0.	0.	1.26	0.00	3271.	0.	0.	0.	
21	144	0	3	75.	70.	0.	NO	5.	0.	0.	0.	1.17	0.00	3409.	15.	3148.	44.	ENTH
	644	0	14	75.	70.	0.	NO	5.	0.	0.	0.	1.07	0.00	3488.	17.	2900.	48.	
MEAN ORIGINAL DESIGN				56.	69.	52.		6.	0.	0.	0.	1.36	0.97	3513.	14.	2887.	16.	
MEAN REDESIGN				62.	67.	46.		8.	30.	9.	5.	1.01	0.31	3108.	15.	1198.	8.	

DEPS PHASE II KEY DATA BASE PARAMETER: ASSEMBLY
PRIMARY SYSTEM

06-JAN-83
PAGE 5

P.A. NO.	BLDG. NO.	CHILLER COOLING CAP	HEATING EFF.	HEAT RECOVERY	HEAT PUMP TYPE	HP HEATING COP	COOLING FUEL TYPE	HOT WATER STORAGE (BTU/BTU CAP)	AUX. KW COOLING VAR.	AUX. KW COOLING CONST	AUX. KW HEATING VAR.	AUX. KW HEATING CONST	S.F. PER TON	HEATING BTU PER SF
11	78 578	0.0 0.0	0.8 0.8			0.0 0.0		0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	53. 50.
12	65 565	2.2 2.2	0.7 0.7			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	203. 226.	119. 107.
13	45 515	3.2 3.7	1.0 0.4			0.0 0.0	E E	0. 0.	0. 0.	9. 10.	0. 15.	0. 0.	156. 280.	130. 678.
14	47 547	2.6 2.6	1.0 1.0			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	2. 2.	215. 231.	71. 72.
15	31 531	0.0 2.5	1.0 1.0			0.0 0.0	E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	58. 78.
16	98 598	0.0 0.0	0.6 0.6			0.0 0.0		0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	255. 42.
17	17 517	2.2 4.3	0.8 0.8			0.0 0.0	E E	0. 0.	0. 4.	0. 5.	1. 1.	0. 0.	177. 436.	58. 59.
18	135 635	0.0 0.0	0.8 0.8			0.0 0.0		0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	68. 54.
19	115 615	1.7 2.0	0.8 0.8			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	260. 270.	57. 39.
20	101 601	2.1 2.1	0.0 0.0			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	322. 744.	0. 0.
21	144 644	1.7 2.9	0.8 0.8		11	0.0 3.0	E E	0. 0.	0. 1.	0. 6.	0. 0.	0. 0.	341. 0.	56. 13.
MEAN ORIGINAL DESIGN		1.4	0.8	0		0.0		0.	0.	1.	0.	0.	239.	79.
MEAN REDESIGN		2.0	0.8	0		3.0		0.	0.	2.	1.	0.	364.	104.

P.A. NO.	BLDG NO.	FLOOR AREA		ORIENT. DFG. FRM NORTH	MAJOR ORIENT.	WINTER INF. (ACH)	WALL BELOW GRADE	U-VALUES				BLOG MASS (LB/SF)			BLOG COLOR	
		GROSS	NET					WALL	ROOF	GLASS	COMPOSITE	WALL	ROOF	FLOOR	WALL	ROOF
1	68	13302.	12931.	358	E-W	0.25	0.	0.18	0.19	0.58	0.19	18.6	1.6	58.8	M	L
	568	13352.	12933.	350	E-W	0.16	28.	0.06	0.05	0.61	0.11	25.1	1.7	58.8	D	L
2	63	19034.	18633.	0		0.90	0.	0.27	0.16	0.75	0.22	98.7	9.2	72.0	M	M
	563	19074.	18513.	0		0.40	0.	0.20	0.15	0.58	0.20	99.1	9.3	72.0	D	L
3	94	54500.	54400.	0		0.15	0.	0.50	0.10	1.13	0.24	37.5	2.0	72.0	M	M
	594	54500.	54400.	0		0.15	0.	0.10	0.10	0.70	0.11	37.5	2.0	72.0	M	M
4	133	100400.	99200.	0	E-W	0.11	0.	0.15	0.10	1.13	0.12	70.0	10.0	63.0	M	M
	633	100400.	99200.	0	E-W	0.11	0.	0.10	0.06	1.13	0.07	70.0	10.0	63.0	M	M
5	7	7615.	7519.	12	N-S	1.00	10.	0.37	0.22	0.65	0.29	77.7	3.6	48.3	M	L
	507	7234.	7230.	0		0.50	10.	0.09	0.07	0.56	0.13	140.0	10.0	70.0	M	L
6	122	132400.	90900.	0		0.00	9.	0.29	0.09	0.84	0.27	97.1	50.9	55.0	M	L
	672	141300.	98152.	0		0.50	1.	0.10	0.06	0.54	0.09	89.4	51.0	70.0	M	L
7	104	40440.	40430.	0	E-W	0.80	0.	0.74	0.18	1.10	0.36	54.0	70.0	62.0	L	M
	604	40440.	40430.	0	E-W	0.40	8.	0.26	0.12	1.06	0.17	79.0	70.0	62.0	L	L
8	130	17650.	17600.	339	E-W	1.50	0.	0.73	1.90	1.10	1.43	73.1	5.3	60.0	M	M
	630	17600.	17599.	330	E-W	1.50	0.	0.56	0.05	0.58	0.22	116.0	5.7	60.0	L	L
9	106	20800.	12406.	35	E-W	0.58	0.	0.54	0.16	1.10	0.33	48.3	55.0	62.5	L	L
	606	19200.	11616.	305	N-S	0.41	0.	0.10	0.16	1.10	0.15	48.4	5.0	64.0	L	L
10	153	4900.	1192.	36	E-W	0.60	0.	0.12	0.05	1.10	0.19	15.0	9.0	50.0	L	M
	653	4900.	1192.	36	E-W	0.60	0.	0.12	0.05	1.10	0.19	15.0	9.0	50.0	L	M
MEAN ORIGINAL DESIGN		41104.	35521.	78.		0.59	2.	0.39	0.31	0.95	0.36	59.0	21.7	60.4		
MEAN REDESIGN		41796.	36127.	103.		0.47	5.	0.17	0.09	0.80	0.14	72.0	17.4	64.2		

P.A. NO.	BIDG NO.	BIDG GLASS AREAS				SKYLIGHT AREA (%ROOF)	GLASS SHADE COEFFICIENT				FXI SHADE	PROCESS LOADS			
		SQ FT	ENVEL	SOUTH	NORTH		SOUTH	NORTH	EAST	WEST		GENERAL K _a /SF	BTUH/SF	SPECIAL K _a /SF	BTUH/SF
1	66	124.	2.	19.	32.	0.	0.55	0.55	0.00	0.55		0.000	0.0	0.001	22.6
	568	126.	2.	38.	25.	21.	0.55	0.55	0.00	0.55	YES	0.000	0.0	0.001	0.0
2	63	465.	4.	28.	0.	0.	1.00	0.00	1.00	1.00		0.000	0.0	0.000	0.0
	563	264.	3.	73.	0.	6.	0.54	0.00	0.00	0.54	YES	0.000	0.0	0.000	0.0
3	94	227.	1.	26.	56.	0.	0.80	0.80	0.80	0.80		0.000	0.0	0.000	0.0
	594	648.	2.	36.	36.	0.	0.94	0.94	0.94	0.94		0.000	0.0	0.000	0.0
4	133	20.	0.	100.	0.	0.	0.94	0.00	0.00	0.00		0.000	0.0	0.000	0.0
	633	20.	0.	100.	0.	0.	0.94	0.00	0.00	0.00		0.000	0.0	0.000	0.0
5	7	230.	4.	0.	21.	0.	0.00	0.81	0.81	0.00		0.000	0.0	0.000	0.0
	507	982.	15.	73.	0.	3.	0.81	0.00	0.81	0.00	YES	0.000	0.0*****		0.0
6	122	9644.	17.	9.	40.	0.	0.70	0.70	0.70	0.70	YES	0.000	0.0	0.000	0.0
	622	4009.	15.	7.	20.	0.	0.23	0.23	0.60	0.23	YES	0.000	0.0	0.000	0.0
7	104	120.	1.	0.	100.	0.	0.00	0.55	0.00	0.00		0.000	0.0	0.000	0.0
	604	640.	3.	84.	16.	0.	0.80	0.55	0.00	0.00	YES	0.000	0.0	0.000	0.0
8	130	560.	6.	44.	44.	5.	0.94	0.94	0.00	0.94	YES	0.001	0.0	0.000	0.0
	630	144.	2.	50.	50.	5.	1.00	1.00	0.00	0.00	YES	0.000	0.0	0.000	0.0
9	106	270.	3.	0.	42.	0.	0.00	0.72	0.00	0.30	YES	0.001	0.0	0.000	0.0
	606	270.	3.	0.	0.	0.	0.00	0.00	0.34	0.30	YES	0.001	0.0	0.000	0.0
10	153	648.	14.	53.	0.	0.	0.88	0.00	0.88	0.88	YES	0.000	0.0	0.000	0.0
	653	597.	13.	41.	11.	1.	0.74	0.74	0.74	0.00	YES	0.000	0.0	0.000	0.0
MEAN ORIGINAL DESIGN		1231.	5.	28.	37.	0.	0.83	0.72	0.84	0.74		0.000	0.0	0.000	2.3
MEAN REDESIGN		770.	6.	50.	16.	3.	0.73	0.67	0.69	0.51		0.000	0.0*****		0.0

REPS PHASE II KEY DATA BASE PARAMETER: STORAGE
LIGHTING SYSTEM

04-JAN-83
PAGE 3

P.A. NO.	BLDG NO.	WATTS PER S.F.	ILLUM. LEVEL	LAMP TYPE (PERCENT TOTAL FLOOR AREA)								CONTROL TYPE (% TOTAL FLOOR AREA)							
				INC	TH	F	HG	HH	RPS	LPS	U	HKR	SW	LV	CPT	PH	DIM	IC	U
1	68	1.5	32.	92.	0.	8.	0.	0.	0.	0.	0.	88.	12.	0.	0.	0.	0.	0.	0.
	566	0.6	31.	0.	0.	100.	0.	0.	0.	0.	0.	0.	4.	0.	0.	96.	0.	0.	0.
2	63	0.9	29.	0.	0.	96.	0.	0.	0.	0.	0.	0.	96.	0.	0.	0.	0.	0.	0.
	563	0.6	18.	0.	0.	37.	0.	0.	37.	0.	0.	0.	26.	0.	0.	48.	0.	0.	0.
3	94	0.5	15.	0.	0.	100.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	594	0.5	15.	0.	0.	100.	0.	0.	0.	0.	0.	0.	1.	0.	0.	99.	0.	0.	0.
4	133	0.6	41.	0.	0.	100.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	633	0.9	41.	0.	0.	16.	0.	0.	84.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
5	7	1.8	67.	0.	0.	100.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	507	1.1	44.	0.	0.	87.	0.	13.	0.	0.	0.	40.	60.	0.	0.	0.	0.	0.	0.
6	122	1.6	48.	2.	0.	36.	0.	0.	62.	0.	0.	51.	49.	0.	0.	0.	0.	0.	0.
	622	1.5	51.	2.	0.	37.	0.	0.	61.	0.	0.	57.	43.	0.	0.	0.	0.	0.	0.
7	104	1.1	21.	0.	0.	100.	0.	0.	0.	0.	0.	90.	10.	0.	0.	0.	0.	0.	0.
	604	0.4	20.	0.	0.	100.	0.	0.	0.	0.	0.	0.	10.	0.	0.	90.	0.	0.	0.
8	130	1.3	39.	87.	0.	13.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	630	0.5	36.	0.	0.	95.	0.	0.	0.	0.	0.	0.	95.	0.	0.	0.	0.	0.	0.
9	106	2.0	0.	0.	0.	100.	0.	0.	0.	0.	0.	92.	8.	0.	0.	0.	0.	0.	0.
	606	2.0	45.	0.	0.	100.	0.	0.	0.	0.	0.	14.	86.	0.	0.	0.	0.	0.	0.
10	153	3.4	43.	0.	0.	100.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	653	2.9	52.	0.	0.	100.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
MEAN ORIGINAL DESIGN		1.5	33.	18.	0.	75.	0.	0.	6.	0.	0.	32.	68.	0.	0.	0.	0.	0.	0.
MEAN REDESIGN		1.1	35.	0.	0.	77.	0.	1.	18.	0.	0.	11.	52.	0.	0.	33.	0.	0.	0.

BEPS PHASE II KEY DATA BASE PARAMETER: STORAGE
SECONDARY SYSTEM

04-JAN-83
PAGE 4

P.A. NO.	BLDG. NO.	SYSTEM ID		T-STAT SET PT.				COOL	DAY	NIGHT	NIGHT	DEAD	W/LIGHT	DSCHG	EXHAUST	ATR	SUPPLY		CFM PER BHP	OUTSIDE AIR			ECON TYPE
		INT	TER	COOL	DAY	NIGHT	NIGHT										HEAT	TEMP		HEAT	RECOVERY	CFM/SF	
1	66	0	7	0.	68.	68.	YES	0.	0.				0.	0.	0.	0.	1.12	0.0031511.	0.	0.	0.	FNTH	
	569	0	15	0.	0.	0.	YES	0.	0.				0.	0.	0.	0.	0.08	0.00	2857.	0.	0.		0.
2	63	0	7	0.	65.	50.	YES	0.	0.				0.	0.	0.	0.	1.16	0.00	6527.	1.	320.	9.	FNTH
	563	0	3	55.	55.	0.	YES	0.	0.				0.	0.	0.	0.	0.17	0.00	3976.	10.	340.	10.	
3	94	0	7	0.	65.	65.	YES	0.	0.				0.	0.	0.	0.	0.45	0.0032533.	0.	60.	12.		
	594	0	3	55.	65.	65.	YES	0.	0.				0.	0.	0.	0.	0.01	0.00	2400.	5.	30.		6.
4	133	3	3	72.	68.	68.	YES	0.	0.				0.	0.	0.	0.	0.21	0.63	827.	10.	2399.	19.	55.
	633	3	3	78.	68.	60.	YES	0.	0.				0.	0.	0.	0.	0.41	0.63	1322.	10.	4229.	34.	
5	7	0	3	75.	70.	60.	YES	0.	0.				0.	0.	0.	0.	0.53	0.00	1333.	10.	400.	44.	70.
	507	0	15	80.	70.	60.	YES	0.	60.				0.	0.	0.	0.	0.47	0.00	2203.	5.	165.	18.	
6	122	7	7	75.	75.	60.	YES	0.	25.	NO			3.	70.	1.27	1.37	724.	26.	30458.	156.			
	622	3	7	75.	75.	60.	YES	0.	25.	NO			36.	70.	1.22	2.53	970.	49.	66606.	342.			
7	104	0	7	0.	65.	55.	YES	0.	0.				0.	0.	0.	0.	0.39	0.00	8316.	2.	380.	19.	
	604	0	7	50.	65.	40.	YES	0.	0.				0.	0.	0.	0.	0.33	0.00	1792.	16.	2144.	107.	
8	130	0	7	0.	65.	0.	NO	0.	0.				0.	0.	0.	0.	1.23	0.0018000.	0.	0.	0.		
	630	0	7	0.	65.	0.	NO	0.	0.				0.	0.	0.	0.	0.28	0.0050000.	0.	0.	0.		
9	106	3	3	75.	70.	0.	NO	0.	0.				0.	0.	0.	0.	0.84	0.99	2933.	0.	0.	0.	
	606	3	3	75.	70.	0.	NO	0.	0.				0.	0.	0.	0.	0.71	0.53	2629.	0.	0.	0.	
10	153	0	7	78.	70.	0.	NO	0.	0.				0.	0.	0.	0.	0.60	0.00	1152.	10.	72.	9.	
	653	0	7	55.	68.	0.	NO	0.	0.				0.	0.	0.	0.	0.68	0.00	2492.	10.	81.	10.	
MEAN ORIGINAL DESIGN					37.	69.	43.		0.	25.			0.	7.	0.78	1.0010386.	6.	3409.	27.				
MEAN REDESIGN					52.	60.	29.		0.	43.			4.	7.	0.44	1.23	7064.	11.	7359.	53.			

REPS PHASE II KEY DATA BASE PARAMETERS STORAGE
PRIMARY SYSTEM

OK-JAP-83
PAGE 5

P.A. NO.	BLDG. NO.	CHILLER COOLING COP	HEATING EFF.	HEAT RECOVERY	HEAT PUMP TYPE	HP HEATING COP	COOLING FUEL TYPE	HOT WATER STORAGE (BTU/PTH CAP)	AUX. KW COOLING VAR.	AUX. KW COOLING CONST	AUX. KW HEATING VAR.	AUX. KW HEATING CONST	S.F. PER TON	HEATING BTU PER SF
1	69 564	2.3 2.7	0.8 0.8		11	0.0 2.7	E E	0. 2.	0. 0.	0. 0.	0. 0.	0. 0.	411. 0.	70. 17.
2	63 563	2.2 2.6	0.8 1.0			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 1.	0. 0.	241. 525.	73. 38.
3	44 574	3.5 3.5	0.8 0.4			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	500. 500.	28. 32.
4	133 643	4.8 1.3	0.6 0.6			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	692. 1105.	34. 15.
5	7 507	2.0 2.5	0.9 1.0			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	389. 363.	72. 15.
6	122 622	3.8 3.9	1.0 1.0	YES YES		0.0 0.0	E E	0. 0.	49. 49.	29. 25.	0. 0.	0. 0.	180. 182.	70. 4.
7	104 604	2.5 0.0	0.7 0.8			0.0 0.0	E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	418. 0.	29. 25.
8	130 630	0.0 0.0	0.8 0.0			0.0 0.0		0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	91. 23.
9	106 606	2.2 2.5	0.7 0.8			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	347. 578.	49. 40.
10	153 653	2.3 2.0	0.8 0.8			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	336. 467.	84. 37.
MEAN ORIGINAL DESIGN		2.6	0.8	1		0.0		0.	5.	3.	0.	0.	390.	60.
MEAN REDESIGN		2.1	0.9	1		2.7		2.	5.	3.	0.	0.	531.	25.

1	10	20	30	40	50	60	70	80	90	100
2	11	22	33	44	55	66	77	88	99	110
3	12	24	36	48	60	72	84	96	108	120
4	13	26	39	52	65	78	91	104	117	130
5	14	28	42	56	70	84	98	112	126	140
6	15	30	45	60	75	90	105	120	135	150
7	16	32	48	64	80	96	112	128	144	160
8	17	34	51	68	85	102	119	136	153	170
9	18	36	54	72	90	108	126	144	162	180
10	19	38	57	76	95	114	133	152	171	190
11	20	40	60	80	100	120	140	160	180	200
12	21	42	63	84	105	126	147	168	189	210
13	22	44	66	88	110	132	154	176	198	220
14	23	46	69	92	115	138	161	184	210	230
15	24	48	72	96	120	144	168	192	216	240
16	25	50	75	100	125	150	175	200	225	250
17	26	52	78	104	130	156	182	208	232	260
18	27	54	81	108	135	162	189	216	240	270
19	28	56	84	112	140	168	196	224	248	280
20	29	58	87	116	145	174	203	232	256	290
21	30	60	90	120	150	180	210	240	264	300
22	31	62	93	124	155	186	217	248	272	310
23	32	64	96	128	160	192	224	256	280	320
24	33	66	99	132	165	198	231	264	288	330
25	34	68	102	136	170	204	238	272	296	340
26	35	70	105	140	175	210	245	280	304	350
27	36	72	108	144	180	216	252	288	312	360
28	37	74	111	148	185	222	259	296	320	370
29	38	76	114	152	190	228	266	304	328	380
30	39	78	117	156	195	234	273	312	336	390
31	40	80	120	160	200	240	280	320	344	400
32	41	82	123	164	205	246	287	328	352	410
33	42	84	126	168	210	252	294	336	360	420
34	43	86	129	172	215	258	301	344	368	430
35	44	88	132	176	220	264	308	352	376	440
36	45	90	135	180	225	270	315	360	384	450
37	46	92	138	184	230	276	322	368	392	460
38	47	94	141	188	235	282	329	376	400	470
39	48	96	144	192	240	288	336	384	408	480
40	49	98	147	196	245	294	343	392	416	490
41	50	100	150	200	250	300	350	400	424	500
42	51	102	153	204	255	306	357	408	432	510
43	52	104	156	208	260	312	364	416	440	520
44	53	106	159	212	265	318	371	424	448	530
45	54	108	162	216	270	324	378	432	456	540
46	55	110	165	220	275	330	385	440	464	550
47	56	112	168	224	280	336	392	448	472	560
48	57	114	171	228	285	342	399	456	480	570
49	58	116	174	232	290	348	406	464	488	580
50	59	118	177	236	295	354	413	472	496	590
51	60	120	180	240	300	360	420	480	504	600
52	61	122	183	244	305	366	427	488	512	610
53	62	124	186	248	310	372	434	496	520	620
54	63	126	189	252	315	378	441	504	528	630
55	64	128	192	256	320	384	448	512	536	640
56	65	130	195	260	325	390	455	520	544	650
57	66	132	198	264	330	396	462	528	552	660
58	67	134	201	268	335	402	469	536	560	670
59	68	136	204	272	340	408	476	544	568	680
60	69	138	207	276	345	414	483	552	576	690
61	70	140	210	280	350	420	490	560	584	700
62	71	142	213	284	355	426	497	568	592	710
63	72	144	216	288	360	432	504	576	600	720
64	73	146	219	292	365	438	511	584	608	730
65	74	148	222	296	370	444	518	592	616	740
66	75	150	225	300	375	450	525	600	624	750
67	76	152	228	304	380	456	532	608	632	760
68	77	154	231	308	385	462	539	616	640	770
69	78	156	234	312	390	468	546	624	648	780
70	79	158	237	316	395	474	553	632	656	790
71	80	160	240	320	400	480	560	640	664	800
72	81	162	243	324	405	486	567	648	672	810
73	82	164	246	328	410	492	574	656	680	820
74	83	166	249	332	415	498	581	664	688	830
75	84	168	252	336	420	504	588	672	696	840
76	85	170	255	340	425	510	595	680	704	850
77	86	172	258	344	430	516	602	688	712	860
78	87	174	261	348	435	522	609	696	720	870
79	88	176	264	352	440	528	616	704	728	880
80	89	178	267	356	445	534	623	712	736	890
81	90	180	270	360	450	540	630	720	744	900
82	91	182	273	364	455	546	637	728	752	910
83	92	184	276	368	460	552	644	736	760	920
84	93	186	279	372	465	558	651	744	768	930
85	94	188	282	376	470	564	658	752	776	940
86	95	190	285	380	475	570	665	760	784	950
87	96	192	288	384	480	576	672	768	792	960
88	97	194	291	388	485	582	679	776	800	970
89	98	196	294	392	490	588	686	784	808	980
90	99	198	297	396	495	594	693	792	816	990
91	100	200	300	400	500	600	700	800	824	1000

APPENDIX I:
DATA DEFINITIONS

ENVELOPE

Gross Floor Area (Square Feet): This is the sum of the areas of the floors of the building, including basements, mezzanines and penthouses (or attics) of headroom height, measured from the exterior face of exterior walls, disregarding protrusions beyond the nominal plane of the wall. Measurements are from the center line of walls separating buildings, including areas occupied by structural elements.

Excluded areas are covered walkways, open roofed-over areas, porches and similar spaces, pipe trenches, exterior terraces or steps, chimneys, roof overhangs, and the like.

Net Floor Area (Square Feet): This is the floor area that is conditioned, i.e., heated and/or cooled. Some examples of areas which may not be conditioned are: stairhalls, elevator and duct shafts, closets, interior toilets, storage spaces, etc.

Orientation: This is the angle from true north of the exposure which is closest to true north.

Major Orientation: This data is extracted only for buildings with four distinct exposure angles. If the sum of the areas of the east and west exposures is greater than the sum of the areas of the north and south exposures, then the major orientation is north-south (N-S). Otherwise, the major orientation is east-west (E-W).

Winter Infiltration (Air Changes per Hour): Infiltration values are based on the rate of the estimated average wind velocity experienced for the season, not the peak conditions for the season.

Wall Below Grade (Percent): This is the sum of the wall areas below grade of every energy simulation area (ESA) divided by the sum of the opaque wall area for all exposures.

Wall U-Value (BTU/Square Foot.Hour): This is the weighted average of the opaque wall U-factor for all wall sections, i.e., the sum of the opaque wall area times the opaque wall U-factor for all exposures divided by the sum of the opaque wall areas.

Roof U-Value (BTU/Square Foot.Hour): This is the weighted average of the roof U-value for all roof sections, i.e., the sum of the roof area times the roof U-factor divided by the sum of the roof areas.

Glass U-Value (BTU/Square Foot Hour): This is the weighted average of the glass U-factor for all exposures, i.e., the sum of the fenestration area times the fenestration U-factor for all exposures divided by the sum of the fenestration areas.

Composite U-Value (BTU/Square Foot Hour): This is the weighted average of the envelope's U-factor, i.e., the sum of the area times the U-factor for the opaque walls, fenestration and opaque doors for all exposures plus skylight area times skylight U-factors plus roof area times roof U-factor divided by the sum of the opaque wall, fenestration, opaque door, skylight and roof areas.

Wall Mass (Lb/Square Foot): This is the sum of the opaque wall density times the opaque wall area for all exposures. Roof and floor mass are calculated accordingly.

Wall Color: Either light, medium or dark (same for roofs).

Glass Area (Square Feet): This is the sum of the fenestration areas for all exposures not including skylight areas.

Glass Area (Percent Envelope): This is the sum of the fenestration areas for all exposures divided by the sum of the opaque walls, fenestration, opaque doors, skylights and roof areas.

Glass Area, Percent South: This is the sum of the fenestration areas for all southern exposures divided by the total fenestration area. A southern exposure has an angle of +180 degrees plus or minus 45 degrees.

Glass Area, Percent North: This is the sum of the fenestration areas for all northern exposures divided by the total fenestration area. A northern exposure is one with an exposure angel equal to the orientation plus or minus 45 degrees.

Skylight Area, Percent Roof: This is the skylight area divided by the roof area plus the skylight area.

Glass Shading Coefficient By Exposure: This is the sum of the fenestration shading coefficient times the fenestration area for all exposures of the same orientation, i.e., north, south, east or west, divided by the sum of the fenestration areas for these exposures. Northern exposures are those with angles equal to the building orientation plus or minus 45 degrees. Eastern exposures have their angle equal to the building orientation 90 degrees plus or minus 45 degrees. South and west exposures are defined similarly.

Process Loads, General: This is the sum of the base loads for domestic hot water, elevators, escalators, toilet exhaust fans, general exhaust fans #1 and general exhaust fans #2.

Process Loads, Special: This is the sum of the base loads such as data processing equipment, kitchen exhaust fans and kitchen equipment or specialized energy using equipment.

LIGHTING

Lighting Watts Per Square Foot: This is the summation of the total number of fixtures times the wattage per fixture for every energy simulation area (ESA), divided by the sum of the net floor areas for every ESA.

Illumination Level (Footcandles): This is the weighted average of all illumination levels per lamp types and per energy simulation areas.

Lamp Type (Percent of Total Floor Area): This is the summation of the net floor area of the ESA times the number of specific fixtures divided by the total number of fixtures for the ESA, then this sum by lamp type is divided by the total sum of the net floor area of every ESA.

Control Type (Percent of Total Floor Area): The calculations for control type area analogous to those performed for lamp type.

SECONDARY SYSTEMS

System Identification: The system ID is the system type with the greatest accumulated supply air volume. The ESA design supply air - cfm - is accumulated by perimeter and interior and by system type. Perimeter ESA has roof, opaque wall, window, opaque door and/or glass door areas as specified.

Deadband Range: This is a special type of controlled system in which neither heating nor cooling is provided when inside design temperature is within the stated range; i.e., cooling is provided only when the temperature is above 78°F and heating is provided only when the temperature is below 72°F. Nothing is provided when the temperature is in the range of 72°F to 78°F.

Discharge Temperature Control: Used with VAV with reheat.

Exhaust Air Heat Recovery, Percent Ventilation: This is the percent of the total minimum outdoor air quantity which has exhaust air heat recovery applied to it.

Exhaust Air Heat Recovery, Percent Efficiency: This is the average percent sensible exhaust heat recovery for secondary systems with exhaust heat recovery.

Supply CFM/Square Foot: The ESA supply CFM for all perimeter ESA and interior ESA are summed separately, then divided by the sum of the perimeter or interior ESA floor areas. The perimeter ESA includes roof, opaque, window, opaque door and/or glass door areas.

CFM / BHP: This is the sum of all ESA supply air cfm divided by the sum of the supply and return for BHP for all systems.

Outside Air: This is the minimum daytime outside air quantity introduced into the building.

Economizer Type: If the system CFM for secondary systems with dry bulb economizers is summed and the system CFM for secondary systems with an enthalpy economizer is summed, and then, if the

two totals exceed 0.5 times the sum of all ESA CFM, then an economizer is specified. The type specified depends on which total, enthalpy CFM or dry bulb CFM, is greater.

PRIMARY SYSTEMS

Cooling COP: This is the sum of the rated input BTUH divided by the sum of the rated output BTUH for the following systems: refrigeration, double bundle condensor, change over unitary heat pumps, direct energy, unitary cooling units, and simulations unitary heat pump. For a condensor water loop heat pump it is the rated output BTUH divided by the rated input KW times 3413.

Heat Efficiency: This is the sum of the rated input BTUH divided by the sum of the rated output BTUH for heating systems.

Chiller Heat Recovery: This is used with the double bundle condensor.

Heat Pump Type: This is the primary system type for the last heat pump specified the output capacity for all heating primary systems.

Cooling Fuel Type: This is the fuel type with the greatest associated cooling output.

Hot Water Storage, Btu/Btu Capacity: This is the sum of the storage capacity for all primary systems divided by the sum of the output capacity for all heating primary systems.

Cooling Auxiliary KW: This is the sum of both the variable and constant cooling system auxiliaries corresponding to those whose energy consumption varies with the output of the primary equipment and those which are constantly on, independent of the primary equipment output.

Heating Auxiliary KW: Calculated as in cooling.

Square Feet Per Ton: This is the sum of the floor area served by the cooling primary systems divided by the sum of the output

capacity for all cooling primary systems.

Heating KBtu/Square Foot: This is the sum of the output capacity for all heating primary systems divided by the sum of the floor area served by the heating primary system.

APPENDIX 2:

DATA EXTRACTIONS -
RESTAURANTS / FAST FOOD AND
MISCELLANEOUS BUILDINGS

APPENDIX 1

DATA COLLECTION
METHODS AND
RESULTS

DEFS PHASE II KEY DATA BASE PARAMETER: RESTAURANTS
ENVELOPE

04-JAN-83
PAGE 1

P.A. NO.	BLDG NO.	FLOOR AREA		ORIENT. DEG. FRM NORTH	MAJOR ORIENT.	WINTER INF. (ACH)	WALL BELOW GRADE	U-VALUES				BLDG MASS (LH/SF)			BLDG COLOR	
		GROSS	NET					WALL	ROOF	GLASS	COMPOSITE	WALL	ROOF	FLOOR	WALL	ROOF
1	85	4033.	2705.	0	N-S	0.00	0.	0.09	0.09	0.55	0.14	30.9	10.9	46.7	M	M
	585	4033.	2695.	0	N-S	0.00	0.	0.05	0.05	0.55	0.09	30.9	10.9	46.7	M	M
2	64	6632.	3990.	42	E-W	0.20	0.	0.11	0.05	0.68	0.10	37.9	75.0	50.0	M	M
	564	6792.	3740.	0	N-S	0.20	12.	0.04	0.04	0.39	0.05	31.9	75.0	50.0	M	M
3	91	4733.	3856.	345	N-S	1.50	0.	0.08	0.05	0.60	0.09	5.0	10.0	50.0	M	M
	591	4643.	3289.	345		1.50	19.	0.07	0.03	0.60	0.07	62.3	10.0	50.0	M	M
4	92	4000.	2650.	360	N-S	0.00	0.	0.11	0.08	1.13	0.17	90.9	20.0	48.0	L	L
	592	4000.	3030.	344		0.00	40.	0.15	0.08	0.66	0.17	91.0	20.0	48.0	L	L
5	10	14000.	4856.	15	N-S	0.25	0.	0.17	0.09	1.10	0.13	85.0	12.0	40.0	M	N
	510	14000.	4968.	0	E-W	0.25	0.	0.10	0.06	0.00	0.08	89.0	16.0	40.0	M	L
6	34	4350.	2910.	329	N-S	1.50	0.	0.19	0.10	0.50	0.17	50.9	9.5	48.0	M	M
	534	5213.	5031.	329	N-S	0.75	46.	0.08	0.03	0.50	0.07	52.5	16.2	48.0	M	L
7	123	4587.	2507.	22	E-W	1.50	0.	0.17	0.04	0.00	0.10	16.7	18.0	46.0	M	M
	623	4587.	2507.	22	E-W	1.25	0.	0.09	0.04	0.65	0.08	17.0	18.0	46.0	M	L
8	147	2990.	2108.	0	N-S	1.00	0.	0.41	0.04	1.06	0.20	119.7	30.0	62.5	L	L
	647	2990.	2108.	0	E-W	1.00	0.	0.07	0.04	0.53	0.06	115.0	30.0	62.5	L	L
MEAN ORIGINAL DESIGN		5666.	3198.	139.		0.74	0.	0.16	0.07	0.70	0.14	54.5	23.2	48.9		
MEAN REDSIGN		5782.	3421.	130.		0.62	15.	0.08	0.05	0.49	0.08	61.2	24.5	48.9		

P.A. NO.	BLDG NO.	FLDG GLASS AREAS				SKYLIGHT AREA (%ROOF)	GLASS SHADE COEFFICIENT				EXT SPACE	PROCESS LOADS			
		SG FT	%EVEL	%SOUTH	%NORTH		SOUTH	NORTH	EAST	WEST		GENERAL K+/SF	GENERAL BTUH/SF	SPECIAL K+/SF	SPECIAL BTUH/SF
1	85	693.	30.	0.	38.	0.	0.00	0.74	0.74	0.56	YES	0.000	0.0	0.009	210.8
	585	478.	22.	0.	49.	0.	0.00	0.79	0.79	0.79	YES	0.000	0.0	0.009	111.6
2	64	478.	13.	31.	31.	0.	0.56	0.56	0.56	0.00	YES	0.000	0.0	0.027	0.0
	564	349.	11.	41.	0.	0.	0.74	0.00	0.74	0.74	YES	0.000	0.0	0.026	0.0
3	91	407.	14.	27.	0.	0.	0.83	0.00	0.83	0.83	YES	0.000	0.0	0.001	248.3
	591	350.	12.	84.	0.	0.	0.83	0.00	0.00	0.83	YES	0.000	0.0	0.002	175.5
4	92	490.	23.	6.	16.	0.	0.95	0.95	0.95	0.95	YES	0.000	0.0	0.605	316.9
	592	803.	45.	59.	0.	0.	0.25	0.00	0.25	0.25	YES	0.000	0.0	0.628	146.7
5	10	32.	1.	0.	34.	0.	0.00	0.90	0.00	0.90	YES	0.000	0.0	0.004	119.1
	510	1.	0.	0.	0.	0.	0.00	0.00	0.00	0.00	YES	0.000	0.0	0.004	119.1
6	34	843.	39.	0.	35.	0.	0.00	0.57	0.57	0.57	YES	0.000	0.0	0.026	86.2
	534	190.	8.	0.	37.	0.	0.00	0.57	0.57	0.57	YES	0.000	0.0	0.021	71.9
7	123	1.	0.	0.	0.	0.	0.00	0.00	0.00	0.00	YES	0.000	0.0	0.007	295.6
	623	168.	6.	62.	0.	1.	0.70	0.00	0.90	0.40	YES	0.000	0.0	0.007	218.0
8	147	41.	2.	0.	0.	0.	0.00	0.00	0.00	0.65	YES	0.000	0.0	0.011	0.0
	647	41.	2.	0.	100.	0.	0.00	0.65	0.00	0.00	YES	0.000	0.0	0.011	0.0
MEAN ORIGINAL DESIGN		373.	15.	8.	19.	0.	0.78	0.75	0.74	0.74		0.000	0.0	0.086	159.6
MEAN REDESIGN		298.	13.	31.	23.	0.	0.63	0.67	0.65	0.60		0.000	0.0	0.089	105.4

REPS PHASE II KEY DATA BASE PARAMETER: RESTAURANTS
LIGHTING SYSTEM

04-JAN-83
PAGE 3

P.A. NO.	BLDG NO.	WATTS		ILLUM. LEVEL	LAMP TYPE (PERCENT TOTAL FLOOR AREA)								CONTROL TYPE (% TOTAL FLOOR AREA)							
		PER S.F.	LEVEL		INC	TH	F	HG	MR	HPS	LPS	O	RKR	SK	LV	CPIN	PH	DIM	TC	U
1	85	1.7	7.	100.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.
	585	1.7	7.	100.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.
2	64	2.5	26.	97.	0.	3.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.
	564	1.6	42.	88.	0.	12.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.
3	91	1.9	14.	90.	0.	10.	0.	0.	0.	0.	0.	0.	0.	14.	0.	0.	0.	84.	0.	0.
	591	2.1	17.	78.	0.	22.	0.	0.	0.	0.	0.	0.	0.	25.	0.	0.	0.	71.	0.	4.
4	92	1.7	21.	81.	0.	19.	0.	0.	0.	0.	0.	0.	20.	80.	0.	0.	0.	0.	0.	0.
	592	1.2	15.	80.	0.	20.	0.	0.	0.	0.	0.	0.	0.	20.	0.	0.	0.	80.	0.	0.
5	10	2.1	20.	100.	0.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	510	1.8	20.	96.	0.	4.	0.	0.	0.	0.	0.	0.	0.	16.	0.	0.	0.	84.	0.	0.
6	34	3.3	40.	94.	0.	6.	0.	0.	0.	0.	0.	0.	85.	15.	0.	0.	0.	0.	0.	0.
	534	1.2	30.	30.	0.	70.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
7	123	2.9	19.	81.	0.	19.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.
	623	2.4	19.	100.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.
8	147	2.1	19.	91.	0.	9.	0.	0.	0.	0.	0.	0.	0.	47.	0.	0.	0.	53.	0.	0.
	647	1.0	19.	98.	0.	2.	0.	0.	0.	0.	0.	0.	0.	15.	0.	0.	0.	85.	0.	0.
MEAN ORIGINAL DESIGN		2.3	21.	92.	0.	8.	0.	0.	0.	0.	0.	0.	38.	32.	0.	0.	0.	30.	0.	0.
MEAN REDESIGN		1.6	21.	84.	0.	16.	0.	0.	0.	0.	0.	0.	0.	22.	0.	0.	0.	78.	0.	1.

REPS PHASE II KEY DATA BASE PARAMETER: RESTAURANTS
SECONDARY SYSTEM

04-JAN-83
PAGE 4

P.A. NO.	BLDG NO.	SYSTEM ID		T-STAT SET PT.				DEAD HAND	%LIGHT HEAT TO RA	DSCHG TEMP CTRL	EXHAUST AIR		SUPPLY		CFM PER BHP	OUTSIDE AIR			ECON TYPE
		INT	PER	COOL	DAY HEAT	NIGHT HEAT	NIGHT HEAT				HEAT RECOVERY %VENT %EFF	CFM/SF PER,INT.	%	CFM		CFM/PER			
1	85	0	3	78.	68.	60.	YES	4.	0.		0.	0.	2.41	0.00	1037.	25.	1633.	13.	60.
	585	0	3	78.	68.	60.	YES	10.	0.		0.	0.	1.51	0.00	1624.	30.	1218.	10.	60.
2	64	0	3	75.	72.	0.	NO	0.	0.		0.	0.	2.21	0.00	1760.	43.	3784.	20.	ENTH
	564	0	2	78.	72.	65.	NO	6.	0.		100.	65.	1.14	0.00	1483.	65.	2893.	15.	
3	91	0	3	75.	75.	65.	YES	0.	0.		0.	0.	3.61	0.00	2529.	10.	1391.	8.	ENTH
	591	0	5	75.	75.	65.	YES	7.	0.	NO	0.	0.	2.50	0.00	548.	10.	823.	5.	
4	92	0	3	75.	72.	72.	YES	0.	0.		0.	0.	4.19	0.00	3086.	29.	3180.	30.	ENTH
	592	0	3	75.	77.	77.	YES	0.	0.		0.	0.	3.56	0.00	783.	19.	2060.	20.	
5	10	0	3	75.	70.	62.	YES	0.	0.		0.	0.	3.32	0.00	2357.	26.	4246.	16.	65.
	510	0	3	75.	70.	62.	YES	0.	0.		0.	0.	2.18	0.00	5280.	11.	1236.	4.	ENTH
6	34	0	3	75.	75.	75.	YES	0.	0.		0.	0.	3.71	0.00	1803.	20.	2160.	16.	ENTH
	534	3	3	75.	75.	55.	YES	0.	0.		0.	0.	2.22	0.48	3846.	5.	400.	3.	
7	123	0	3	75.	70.	50.	NO	8.	50.		0.	0.	2.55	0.00	2133.	25.	1600.	13.	ENTH
	623	0	3	75.	70.	50.	NO	13.	50.		0.	0.	2.55	0.00	2133.	25.	1600.	16.	
8	147	0	3	75.	70.	70.	YES	5.	0.		0.	0.	2.09	0.00	2205.	10.	441.	4.	64.
	647	0	3	75.	70.	0.	NO	5.	0.		0.	0.	1.23	0.00	1439.	10.	259.	2.	
MEAN ORIGINAL DESIGN				75.	72.	57.		6.	50.		0.	0.	3.01	0.00	2114.	23.	2304.	15.	
MEAN REDESIGN				76.	72.	54.		8.	50.		12.	8.	2.12	0.48	2142.	22.	1311.	9.	

SEPS PHASE II KEY DATA BASE PARAMETER: RESTAURANTS
PRIMARY SYSTEM

06-JAN-83
PAGE 5

P.A. NO.	BLDG. NO.	CHILLED COOLING COP	HEATING EFF.	HEAT RECOVERY	HEAT PUMP TYPE	HP HEATING COP	COOLING FUEL TYPE	HOT WATER STORAGE (RTU/RTU CAP)	AUX. KW COOLING VAP.	CONST	AUX. KW HEATING VAP.	CONST	S.F. PER TON	HEATING RTU PER SF
1	85 585	2.8 2.8	0.7 0.8			0.0 0.0	E E	0. 0.	0. 0.	3. 3.	0. 0.	0. 0.	92. 113.	172. 96.
2	64 564	2.7 2.7	0.8 0.9			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	95. 150.	368. 241.
3	71 591	2.2 2.7	0.8 0.9			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	98. 97.	354. 237.
4	92 592	2.7 2.9	0.8 0.8			0.0 0.0	E E	0. 0.	8. 0.	0. 6.	0. 0.	0. 0.	88. 107.	194. 318.
5	10 510	2.8 2.7	0.8 0.8			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	1. 1.	1. 0.	119. 171.	278. 75.
6	34 534	2.4 2.4	0.7 0.8			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 1.	0. 0.	104. 241.	155. 33.
7	123 623	2.0 2.0	0.8 0.8			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	157. 157.	164. 118.
8	137 647	2.1 2.1	0.7 0.9			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	0. 0.	0. 0.	143. 216.	133. 95.
MEAN ORIGINAL DESIGN		2.4	0.8	0		0.0		0.	1.	0.	0.	0.	112.	227.
MEAN REDESIGN		2.5	0.8	0		0.0		0.	0.	1.	0.	0.	156.	152.

P.A. NO.	BLDG NO.	FLOOR AREA		ORIENT. DEG. FR NORTH	MAJOR ORIENT.	WINTER INF. (ACH)	WALL RELIN GRADE	U-VALUES				BLDG MASS (LB/SF)			BLDG COLOR	
		GROSS	NET					WALL	ROOF	GLASS	COMPOSITE	WALL	ROOF	FLOOR	WALL	ROOF
1	70 570	2317. 2554.	1631. 703.	0 0	E-W E-W	1.50 0.50	0. 0.	0.20 0.05	0.12 0.07	1.10 0.39	0.28 0.09	81.8 80.3	12.0 12.0	50.0 50.0	M M	L L
2	100 600	2470. 2530.	1394. 1424.	0 0	N-S E-W	0.15 0.15	0. 13.	0.31 0.16	0.05 0.05	1.13 0.58	0.28 0.15	84.0 84.0	91.0 91.0	50.0 50.0	L L	M M
3	108 609	2116. 2161.	1211. 1211.	0 0	E-W E-W	0.75 0.00	0. 16.	0.13 0.09	0.05 0.03	1.13 0.65	0.22 0.12	55.1 74.0	11.0 15.0	55.0 55.0	M M	M L
4	18 516	2200. 2100.	1730. 1338.	325 0	N-S 0	1.00 0.80	0. 23.	0.47 0.06	0.12 0.03	1.10 0.52	0.37 0.10	64.7 85.0	3.4 10.1	97.0 97.0	M L	M M
5	105 605	2260. 2260.	1211. 1280.	0 0	E-W E-W	1.00 0.55	0. 0.	0.24 0.09	0.21 0.07	1.10 0.62	0.28 0.13	38.7 45.9	10.2 10.3	47.0 47.0	M M	M M
6	110 610	1780. 1734.	1102. 839.	41 41	N-S N-S	0.25 0.50	0. 5.	0.10 0.09	0.04 0.04	0.62 0.58	0.10 0.10	60.0 60.0	12.0 15.0	100.0 100.0	M M	D M
7	150 650	2760. 2760.	1890. 1640.	14 14	E-W N-S	1.00 0.95	0. 0.	0.07 0.06	0.03 0.03	1.09 0.48	0.21 0.11	54.0 58.0	23.0 23.0	48.0 48.0	D L	M L
MEAN ORIGINAL DESIGN		2272.	1453.	54.		0.81	0.	0.22	0.09	1.04	0.25	66.1	23.2	63.9		
MEAN REDESIGN		2300.	1205.	8.		0.49	8.	0.09	0.05	0.55	0.11	69.6	25.2	63.9		

DEPS PHASE II KEY DATA BASE PARAMETER: EAST FOOD
ENVELOPE

04-JAN-83
PAGE 2

P.A. NO.	BLOG NO.	WLDG GLASS AREAS				KEYLIGHT AREA (%ROOF)	GLASS SHADE COEFFICIENT				FYI SHADE	PROCESS LOADS			
		SQ FT	%ENVEL	%SOUTH	%NORTH		SOUTH	NORTH	EAST	WEST		GENERAL K _h /SF	BTUH/SF	SPECIAL K _h /SF	BTUH/SF
1	70	641.	21.	35.	34.	0.	0.71	0.71	0.00	0.71	YES	0.000	0.0	0.075	0.0
	570	333.	14.	40.	30.	0.	0.35	0.35	0.00	0.35	YES	0.000	0.0	0.054	0.0
2	100	568.	24.	0.	43.	0.	0.00	0.67	0.67	0.67	YES	0.001	0.0	0.027	24.3
	600	536.	28.	9.	59.	0.	0.57	0.57	0.00	0.57	YES	0.001	0.0	0.026	23.7
3	108	590.	24.	33.	36.	0.	0.81	0.83	0.81	0.00	YES	0.000	0.0	0.055	0.0
	608	386.	25.	39.	27.	0.	0.57	0.57	0.57	0.00	YES	0.000	0.0	0.054	0.0
4	16	490.	21.	47.	0.	0.	0.95	0.90	0.95	0.95	YES	0.000	0.0	0.048	0.0
	518	427.	31.	70.	12.	0.	0.71	0.71	0.71	0.00	YES	0.000	0.0	0.050	0.0
5	105	223.	15.	0.	57.	0.	0.00	0.95	0.95	0.95		0.000	0.0	0.028	252.2
	605	251.	20.	0.	62.	0.	0.00	0.80	0.45	0.45		0.000	0.0	0.028	252.2
6	110	184.	12.	8.	16.	0.	0.81	0.81	0.81	0.00		0.000	0.0	0.014	202.2
	610	184.	13.	8.	16.	0.	0.81	0.81	0.63	0.00		0.000	0.0	0.008	207.6
7	150	685.	35.	18.	32.	0.	0.94	0.94	0.94	0.94	YES	0.000	0.0	0.010	36.2
	650	525.	26.	12.	34.	1.	0.56	0.56	0.56	0.56	YES	0.000	0.0	0.010	36.2
MEAN ORIGINAL DESIGN		463.	22.	20.	31.	0.	0.84	0.82	0.86	0.84		0.000	0.0	0.037	73.6
MEAN REDESIGN		377.	22.	25.	34.	0.	0.59	0.62	0.58	0.48		0.000	0.0	0.033	74.3

REPS PHASE II KEY DATA BASE PARAMETER: FAST FOOD
LIGHTING SYSTEM

04-JAN-81
PAGE 3

P.A. NO.	BLDG NO.	WATTS PER S.F.	ILLUM. LEVEL	LAMP TYPE (PERCENT TOTAL FLOOR AREA)								CONTROL TYPE (% TOTAL FLOOR AREA)							
				INC	TH	F	HG	PH	HPS	LPS	I	RKP	SW	LV	CPIR	PH	DIM	TC	O
1	70	3.9	42.	38.	0.	61.	0.	0.	0.	0.	0.	84.	15.	0.	0.	0.	0.	0.	0.
	570	2.8	17.	66.	0.	31.	0.	0.	0.	0.	0.	0.	97.	0.	0.	0.	0.	0.	0.
2	100	2.2	48.	83.	0.	17.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.
	600	1.2	50.	77.	0.	23.	0.	0.	0.	0.	0.	12.	0.	0.	0.	88.	0.	0.	0.
3	108	3.3	66.	6.	0.	94.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	608	2.6	35.	46.	0.	54.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
4	16	2.5	63.	53.	0.	47.	0.	0.	0.	0.	0.	82.	18.	0.	0.	0.	0.	0.	0.
	518	2.1	51.	26.	0.	62.	0.	0.	0.	0.	0.	0.	66.	0.	0.	23.	0.	0.	0.
5	105	4.1	19.	63.	0.	37.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.
	605	4.1	25.	66.	0.	31.	0.	0.	0.	0.	0.	97.	0.	0.	0.	0.	0.	0.	0.
6	110	2.1	39.	84.	0.	16.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.
	610	0.9	35.	100.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.
7	150	4.3	39.	57.	0.	43.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	650	1.0	21.	65.	0.	35.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
MEAN ORIGINAL DESIGN		3.2	45.	55.	0.	45.	0.	0.	0.	0.	0.	67.	33.	0.	0.	0.	0.	0.	0.
MEAN REDESIGN		2.1	33.	64.	0.	34.	0.	0.	0.	0.	0.	30.	52.	0.	0.	16.	0.	0.	0.

REPS PHASE II KEY DATA BANK PARAMETER: FAST FOOD
SECONDARY SYSTEM

04-JAN-83
PAGE 4

P.A. NO.	RLOG NO.	SYSTEM ID		T-STAT SET PT.				DEAD HAND	HEAT TO RA	PSCHG TEMP CTRL	EXHAUST AIR		SUPPLY		CFM PER RHP	OUTSIDE AIR			FCOM TYPE
		INT	PPF	COOL	DAY	NIGHT	NIGHT				HEAT	RECOVERY	CFM/SF	PER,INT.		%	CFM	CFM/PER	
1	70	0	3	75.	70.	70.	YES	0.	0.		0.	0.	3.87	0.00	3511.	21.	1300.	14.	65.
	570	0	15	78.	70.	69.	YES	0.	0.		0.	0.	3.07	0.00	3592.	26.	559.	5.	65.
2	100	0	3	75.	75.	75.	YES	0.	0.		0.	0.	2.87	0.00	1334.	10.	400.	6.	
	600	15	15	75.	75.	45.	YES	0.	0.		0.	0.	2.90	2.89	1649.	10.	412.	5.	ENTH
3	108	0	3	72.	70.	70.	YES	0.	0.		0.	0.	5.04	0.00	3631.	25.	1525.	16.	
	608	0	3	72.	70.	70.	YES	0.	0.		0.	0.	4.71	0.00	4751.	10.	570.	6.	ENTH
4	18	0	3	75.	70.	70.	YES	0.	0.		0.	0.	3.82	0.00	2000.	11.	743.	15.	
	512	0	15	78.	68.	55.	YES	10.	0.		0.	0.	3.59	0.00	2182.	13.	640.	13.	ENTH
5	105	0	3	78.	72.	72.	YES	0.	45.		0.	0.	3.10	0.00	1630.	20.	750.	10.	
	605	0	3	78.	72.	62.	YES	0.	45.		0.	0.	2.78	0.00	1801.	25.	891.	12.	55.
6	110	0	3	75.	68.	55.	YES	7.	0.		0.	0.	3.39	0.00	2671.	13.	489.	6.	
	610	0	15	75.	68.	55.	YES	7.	0.		0.	0.	3.58	0.00	3000.	33.	999.	12.	ENTH
7	150	0	3	75.	70.	0.	NO	15.	0.		0.	0.	2.41	0.00	5000.	19.	875.	9.	
	650	0	3	75.	70.	0.	NO	5.	0.		0.	0.	2.56	0.00	5316.	20.	840.	12.	ENTH
MEAN ORIGINAL DESIGN				75.	71.	59.		11.	45.		0.	0.	3.50	0.00	2825.	17.	869.	11.	
MEAN REDESIGN				76.	70.	50.		7.	45.		0.	0.	3.31	2.89	3184.	20.	702.	9.	

DEPS PHASE II KEY DATA BASE PARAMETER: FAST FLOOD
PRIMARY SYSTEM

06-JAN-83
PAGE 5

P.A. NO.	REDG. NO.	CHILLER COOLING COP	HEATING EFF.	HEAT RECOVERY	HEAT PUMP TYPE	HP HEATING COP	COOLING FUEL TYPE	HOT WATER STORAGE (RTU/RTU CAP)	AUX. KW COOLING VAR. CONST	AUX. KW HEATING VAR. CONST	S.F. PER TON	HEATING BTU PER SF
1	70 570	2.7 2.5	0.8 1.0			0.0 0.0	E E	0. 0.	2. 0.	0. 0.	85. 46.	230. 11.
2	100 600	2.1 2.8	0.7 0.0			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	171. 137.	202. 0.
3	108 600	2.7 2.9	0.8 0.8			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	102. 120.	226. 276.
4	18 518	2.7 2.7	1.0 1.0			0.0 0.0	E E	0. 0.	0. 2.	0. 0.	71. 79.	124. 15.
5	105 605	3.2 2.6	0.7 0.8			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	77. 104.	277. 250.
6	110 610	2.1 2.2	0.7 0.0			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	73. 114.	313. 0.
7	150 650	2.1 2.1	0.7 1.0			0.0 0.0	E E	0. 0.	0. 0.	0. 0.	419. 419.	175. 36.
MEAN ORIGINAL DESIGN		2.5	0.8	0		0.0		0.	0.	0.	143.	221.
MEAN REDESIGN		2.5	0.9	0		0.0		0.	0.	0.	146.	77.

PEPS PHASE II KEY DATA BASE PARAMETER: MISCELLANEOUS
ENVELOPE

06-JAN-83
PAGE 1

P.A. NO.	BLDG NO.	FLOOR AREA		ORIENT. DEG. FRP NORTH	MAJOR ORIENT.	PINTER INF. (ACH)	WALL BELOW GRADE	U-VALUES				BLDG MASS (LB/SF)			BLDG COLOR	
		GROSS	NET					WALL	ROOF	GLASS	COMPOSITE	WALL	ROOF	FLOOR	WALL	ROOF
1	83	8188.	7995.	0	E-W	0.00	28.	0.12	0.06	0.60	0.14	90.5	5.8	26.0	D	D
	583	8047.	6410.	0	E-W	0.00	25.	0.07	0.05	0.47	0.09	77.4	4.8	55.9	M	L
2	24	27700.	23100.	341	E-W	0.50	15.	0.14	0.11	1.10	0.22	17.4	30.0	37.5	L	L
	574	27000.	22500.	341	W-S	0.50	76.	0.12	0.10	0.61	0.13	14.0	30.0	60.0	L	L
3	54	7600.	7200.	45	W-S	0.20	0.	0.04	0.03	0.96	0.10	64.0	10.0	40.0	D	D
	558	7400.	7200.	0	E-W	0.20	0.	0.04	0.03	0.00	0.04	64.0	10.0	40.0	M	L
4	124	33900.	26415.	354		0.50	14.	0.18	0.07	0.49	0.15	78.3	10.0	50.0	M	D
	624	31515.	27360.	0	E-W	0.50	18.	0.07	0.03	0.49	0.10	54.6	10.0	50.0	M	D
5	90	18100.	17713.	0		0.00	0.	0.05	0.04	1.13	0.06	11.7	5.7	50.0	L	M
	570	18304.	14865.	0	E-W	0.70	0.	0.05	0.04	0.46	0.09	11.7	5.7	50.0	L	M
MEAN ORIGINAL DESIGN		19098.	16485.	148.		0.24	11.	0.11	0.06	0.86	0.14	52.4	12.3	40.7		
MEAN REDESIGN		18453.	15667.	68.		0.38	24.	0.07	0.05	0.41	0.09	44.3	12.1	51.2		

INFORMATION ON GLASS & SKYLIGHT AREAS, GLASS SHADE COEFFICIENTS AND PROCESS LOADS NOT AVAILABLE

REPS PHASE II KEY DATA BASE PARAMETER: MISCELLANEOUS
LIGHTING SYSTEM

04-JAN-83
PAGE 3

P.A. NO.	BLDG NO.	WATTS PER S.F.	ILLUM. LEVEL	LAMP TYPE (PERCENT TOTAL FLOOR AREA)								CONTROL TYPE (% TOTAL FLOOR AREA)							
				INC	TH	F	HG	MH	HPS	LPS	0	BKR	SW	LV	CPTR	FR	DIM	1C	-0
1	83	2.1	66.	30.	0.	35.	0.	31.	0.	0.	0.	1.	95.	0.	0.	0.	0.	0.	0.
	SR3	1.8	48.	9.	0.	87.	2.	0.	0.	0.	0.	24.	74.	0.	0.	0.	0.	0.	0.
2	24	2.2	54.	40.	0.	60.	0.	0.	0.	0.	0.	58.	42.	0.	0.	0.	0.	0.	0.
	524	1.0	39.	8.	0.	92.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
3	58	0.4	50.	100.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	558	0.2	58.	0.	0.	100.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
4	124	2.1	29.	31.	6.	38.	0.	25.	0.	0.	0.	0.	97.	0.	0.	0.	3.	0.	0.
	624	1.5	31.	32.	3.	50.	0.	0.	12.	0.	0.	0.	90.	0.	0.	0.	0.	0.	0.
5	90	1.4	60.	24.	0.	76.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
	590	2.4	55.	40.	0.	60.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
MEAN ORIGINAL DESIGN		1.7	52.	45.	1.	42.	0.	11.	0.	0.	0.	12.	87.	0.	0.	0.	1.	0.	0.
MEAN REDESIGN		1.4	45.	18.	1.	78.	0.	0.	2.	0.	0.	5.	93.	0.	0.	0.	0.	0.	0.

PEPS PHASE II PEY DATA BASE PARAMETER: MISCELLANEOUS
SECONDARY SYSTEM

04-JAN-83
PAGE 4

P.A. NO.	BLDG. NO.	SYSTEM ID		T-STAT SET PT.				HEAT TO RA	TEMP CTRL	EXHAUST AIR RECOVERY	SUPPLY CFM/SE PER INT.	CFM PER BHP	OUTSIDE AIR			ECON TYPE			
		1ST FFL	2ND FFL	COOL	DAY	NIGHT	NIGHT						%	CFM	CFM/PER				
1	83	3	3	78.	68.	60.	YES	6.	55.	NO	0.	0.	1.10	0.29	1977.	5.	323.	11.	ENTH
	583	7	5	78.	68.	60.	YES	6.	0.		0.	0.	0.53	0.26	967.	2.	73.	2.	ENTH
2	24	6	6	75.	70.	70.	YES	0.	20.	0.	0.	0.	1.40	1.19	1128.	29.	8960.	72.	60.
	524	6	6	75.	75.	75.	YES	0.	0.		0.	0.	0.68	0.71	1012.	17.	2597.	76.	55.
3	54	0	14	75.	65.	0.	YES	0.	0.	0.	0.	0.	0.13	0.00	1500.	2.	48.	2.	
	554	0	0	55.	70.	65.	YES	0.	0.		0.	0.	0.00	0.00	0.	0.	0.	0.	
4	124	7	7	55.	70.	65.	YES	0.	0.	0.	0.	0.	0.67	0.16	2947.	28.	4720.	21.	
	624	7	7	70.	70.	64.	YES	0.	0.		0.	0.	0.86	0.50	5687.	6.	1306.	6.	
5	94	0	3	80.	70.	55.	YES	0.	0.	0.	0.	0.	0.60	0.00	3693.	0.	0.	0.	
	599	0	7	55.	70.	55.	NO	0.	0.		0.	0.	0.72	0.00	1534.	4.	399.	10.	
MEAN ORIGINAL DESIGN				73.	69.	50.		6.	37.		0.	0.	0.82	0.55	2249.	13.	2810.	21.	
MEAN REDESIGN				67.	71.	64.		6.	0.		0.	0.	0.56	0.49	1840.	6.	875.	9.	

PEPS PHASE II KEY DATA BASE PARAMETERS - MISCELLANEOUS
PRIMARY SYSTEM

04-JAN-83
PAGE 5

P.A. NO.	BLDG. NO.	CHILLER COOLING COP	HEATING EFF.	HEAT RECOVERY	HEAT PUMP TYPE	HP HEATING COP	COOLING FUEL TYPE	HOT WATER STORAGE (LIT/RTU CAP)	AUX. KW COOLING VAP.	CONST	AUX. KW HEATING VAP.	CONST	R.F. PER TUN	HEATING BTU PER SF
1	84	2.5	0.8			0.0	F	0.	0.	2.	0.	0.	377.	85.
	593	2.3	0.8			0.0	F	0.	0.	0.	0.	0.	814.	20.
2	74	2.8	1.0			0.0	E	0.	0.	9.	0.	0.	235.	38.
	521	2.6	1.0			0.0	E	0.	0.	8.	0.	0.	785.	20.
3	58	2.5	1.0			0.0	E	0.	0.	0.	0.	0.	1200.	21.
	558	0.0	1.0			0.0		0.	0.	0.	0.	0.	0.	8.
4	124	0.0	1.0			0.0		0.	0.	0.	0.	0.	0.	63.
	624	1.0	1.0			0.0	E	0.	0.	0.	0.	0.	0.	17.
5	27	3.0	0.8			0.0	E	0.	0.	0.	0.	0.	547.	33.
	599	0.0	0.8			0.0		0.	0.	0.	0.	0.	0.	25.
MEAN ORIGINAL DESIGN		2.2	0.9	0		0.0		0.	0.	2.	0.	0.	589.	48.
MEAN REDESIGN		1.2	0.9	0		0.0		0.	0.	2.	0.	0.	600.	18.

DISTRIBUTION

No. of
Copies

No. of
Copies

OFFSITE

25 Ted Kurkowski
Office of Building Energy
Research and Development
U.S. Department of Energy
Washington, D.C. 20545

27 DOE Technical Information
Center

Jerold W. Jones
University of Texas at Austin
Dept. of Mechanical Engineering
Engineering Teaching Center
26 & San Jacinto, Rm. 7.140
Austin, TX 78712

Huber Buehrer
Buehrer & Stough
Architects & Engineers
4246 Sylvania Avenue
Toledo, OH 43623

Earl Kennett
AIA Foundation
1735 New York Avenue
Washington, DC 20006

Richard Rush
AIA Foundation
1735 New York Avenue
Washington, DC 20006

Jim Barnett
B114
Bldg. 226
National Bureau of Standards
Washington, DC 20234

David Conover
NCBCS
481 Carlisle Drive
Herndon, VA 22070

Bill Pennington
Mail Station 24
California Energy Commission
1516 9th Street
Sacramento, CA 95814

Elizabeth A. Chase
TVA
400 Commerce Ave
Knoxville, TN 37902

John Holton
Burt Hill Kosar Rittelmann
Associates
440 First Street, NW
Suite 500
Washington, DC 20001

Ron Kamerud
Lawrence Berkeley Laboratories
1 Cyclotron Road, Bldg. 90
Berkeley, CA 94720

Tom Von Mueller
Bonneville Power Administration
P.O. Box 3621
Portland, OR 97208

Roger Carl-Smith
Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, TN 37830

Arnold L. Windman
Syska & Hennessy Inc.
11 West 42nd St
New York, NY 10036

Richard Kutina
American Gas Association
1515 Wilson Blvd.
Arlington, VA 22209

No. of
Copies

Sanford Selman
Edison Electric Institute
1111 19th St NW
Washington, DC 22036

Noel Leary
BOMA International
1250 Eye Street
Suite 200
Washington, DC 20005

Tom Potter
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

Roger McDonald
Brookhaven National Laboratory
Upton, NY 11973

Harrison Fraker
Princeton Energy Group
575 Ewing St.
Princeton, NJ 08540

- 5 Joe Deringer
The Deringer Group
111 7th Street, NE
Washington, DC 20002-6023

- 5 S. Moreno
W. S. Fleming & Associates
536 7th Street, S.E.
Washington, DC 20003

No. of
Copies

- 5 Harry Misuriello
W. S. Flemming & Associates
536 7th Street, S.E.
Washington, DC 20003

Library
Florida State Energy Center
300 State Road 401
Cape Canaveral, FL 32920

ONSITE

DOE Richland Operations Office

H. E. Ransom
O. R. Segna

Pacific Northwest Laboratory

M. J. King
S. H. Pansky
R. W. Reilly
R. A. Stokes
J. L. Stoops (10)
Energy System Library
Publishing Coordinator (2)
Technical Information (5)