Subcontractor Report

**Development of a Methodology
for Defining Whole-Building Energy
Design Targets for Commercial
Buildings**

**Phase 2, Development
Concept Stage Report**

Volume 3: Workshop Summaries

September 1990

**Prepared by the American Society of Heating,
Refrigerating, and Air-Conditioning Engineers, Inc.,
for Pacific Northwest Laboratory
under Contract DE-AC06-76RLO 1830
with the U.S. Department of Energy**

**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 Battelle Memorial Institute, nor any of their employees, makes any warranty, expressed 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, or Battelle Memorial Institute. 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 MEMORIAL INSTITUTE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831;
prices available from (615) 576-8401. FTS 626-8401.

Available to the public from the National Technical Information Service,
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

NTIS Price Codes, Microfiche A01

Printed Copy

Price Code	Page Range	Price Code	Page Range
A02	1- 10	A15	326-350
A03	11- 50	A16	351-375
A04	51- 75	A17	376-400
A05	76-100	A18	401-425
A06	101-125	A19	426-450
A07	126-150	A20	451-475
A08	151-175	A21	476-500
A09	176-200	A22	501-525
A10	201-225	A23	526-550
A11	226-250	A24	551-575
A12	251-275	A25	576-600
A13	276-300	A99	601-Up
A14	301-325		

**Development of a Methodology for
Defining Whole-Building Energy
Design Targets for Commercial
Buildings**

**Phase 2, Development
Concept Stage Report**

Volume 3: Workshop Summaries

Compiled by
J. W. Jones^(a)
J. J. Deringer^(b)
J. D. Hall^(c)

September 1990

**Prepared by the American Society of Heating,
Refrigerating, and Air-Conditioning Engineers, Inc.,
for Pacific Northwest Laboratory
under Contract DE-AC06-76RLO 1830
with the U.S. Department of Energy
under Agreement 007099**

**Pacific Northwest Laboratory
Richland, Washington 99352**

-
- (a) American Society of Heating, Refrigerating,
and Air-Conditioning Engineers, Inc.
(b) American Institute of Architects
(c) The Deringer Group, Riva, Maryland

Project Perspective

The potential advantages of performance-based commercial building design guidelines have been recognized for some time. However, buildings industry acceptance of such performance guidelines has been slow, largely because of concern over the equity of the proposed procedures and the difficulty of applying them to design practice. The buildings industry currently needs a well-defined, easy-to-use methodology for setting target guidelines and for determining compliance with those guidelines.

To hasten industry acceptance and, ultimately, realization of the energy conservation benefits, the U.S. Department of Energy (DOE) Office of Building Technologies (formerly the Office of Buildings and Community Systems) asked the Pacific Northwest Laboratory (PNL) to develop performance-based guidelines for assessing energy efficiency in commercial building design. These guidelines, termed whole-building energy targets, would be indices or yardsticks with which to measure the annual energy performance of an entire building rather than of individual building components or subsystems.

In 1985, the Whole-Building Energy Design Targets project began as part of the Building System Integration Program (BSIP) managed by PNL for DOE. The BSIP comprises a number of research projects dealing with issues of whole-building energy use and systems integration.

The primary focus of the Targets project is to develop a flexible methodology for setting target guidelines and determining compliance with them, rather than to determine numerical target values. Because the problem is so complex, computer software will be developed to implement the methodology. The software is referred to as the Targets model.

The Targets project is a two-phase effort. In Phase 1, Planning, the project team--design professionals from various segments of the industry--was assembled to determine the research necessary for developing the Targets methodology. In the first stage of Phase 2, Development, the project team sought to define the technical and software development concepts upon which the overall Targets methodology will be based. The concept stage work is documented in four volumes, of which this is the third. The other volumes are

- Volume 1: Summary Report
- Volume 2: Technical Concept Development Task Reports
- Volume 4: Software Concept Development Task Reports.

The energy simulation and building cost module development tasks were performed by project team members representing the American Institute of Architects, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., and the Illuminating Engineering Society of North America. This third volume of the Phase 2 report presents the minutes and summarizes the comments and recommendations provided by experts in the fields of energy simulation and building cost estimating during two separate workshops. The ideas and advice offered by these invited consultants helped determine the direction of the module development tasks documented in Volume 2 of this report.

Contents

Project Perspective	iii
1.0 Introduction	1.1
2.0 Building Energy Simulation Performance Workshop	2.1
2.1 Workshop Minutes	2.1
2.2 Consultant Comments	2.8
3.0 Building Cost Workshop	3.1
3.1 Workshop Minutes	3.1
3.2 Consultant Comments	3.10

1.0 Introduction

The Whole-Building Energy Design Targets project is being conducted for the U.S. Department of Energy (DOE) by the Pacific Northwest Laboratory (PNL). The objective of the project is to develop a flexible methodology for setting energy performance guidelines with which architects, engineers, planners, and owners can assess energy efficiency in commercial building design.

Because the generation of energy-performance-based design guidelines for commercial buildings is a complex process, computer software will be developed to implement the Targets methodology. The software is referred to as the Targets model.

Among the innovative features offered by the proposed software are the ways in which building energy simulation and cost estimating will be handled. First, the model will enable building designers to generate targets appropriate to a specific design. The resulting custom targets will reflect building internal load levels and occupancy patterns as well as climate, siting, and other design constraints inherent in a specific building. Second, the Targets model will use project-specific costs for energy and for construction as input. Consequently, the targets will reflect an appropriate balance of energy and economic considerations for each specific design.

Two elements of the Targets model--the energy simulation module and the building cost module, described in Volume 2 of this report--are particularly critical to the overall success of the methodology. For this reason, experts in the fields of energy simulation and building cost estimating were consulted during the concept development phase of the Targets project. Each group met with project staff in separate workshops to share expertise and offer ideas and suggestions for developing these two modules.

This volume, the third in the four-volume report on the Targets project concept stage, contains the minutes of the workshops as well as summaries of the experts' written comments prepared at the close of each workshop. In Section 2, the building energy simulation workshop is summarized. Section 3 provides a summary of the building cost workshop.

2.0 Building Energy Simulation Performance Workshop

After defining the general scope of the proposed energy simulation module, its operating characteristics, and the attributes needed to meet Targets project objectives, the project team organized a meeting with experts in energy simulation. The building energy simulation performance workshop was held in Washington, D.C., on March 14-15, 1988. What follows are the workshop minutes, along with summaries of the written comments and suggestions provided by the nine participating consultants. The information in this section was compiled by Jerold Jones.

2.1 Workshop Minutes

The consultants who participated in the workshop were as follows:

Mick Schwedler, Trane Company
Chip Barnaby, BSG Software
Robert Busch, R. D. Busch Associates
Jim Fireovid, The Fleming Group
Jim Pegues, Carrier Corporation
James Hall, Carrier Corporation
Dan Seth, Public Works, Canada
Fred Winkelman, Lawrence Berkeley Laboratory
Doug Hittle, Colorado State University

Targets project team representatives included the following individuals:

Jerold Jones, University of Texas at Austin
Joe Deringer, The Deringer Group
Dru Crawley, Pacific Northwest Laboratory
Brian Johnson, Pacific Northwest Laboratory
Carol Gardner, U.S. Department of Energy

MONDAY MORNING 3/14/88:

In the first workshop session, Jerry Jones gave an overview of the project goals and objectives. During this presentation a number of questions and issues were raised. They are recapped below.

Hittle	Asked about the level of project effort (time and budget), the current project status and the composition of the project team.
Crawley and Jones	Reviewed project scope and indicated that it was a multiyear effort with a budget that will depend on the availability of funds on a year-by-year basis.
Barnaby	Raised the issue of design priorities that override energy concerns (11 ft of single-pane glass for display windows in a retail store in Bismarck, ND, or 11 W/ft ² for lighting in retail space).
Jones	Indicated that this issue is being specifically addressed in the development of the methodology.

- Busch Asked how speculative buildings would be addressed.
- Jones The speculative building issue will always be with us--the only response is to provide some flexibility for examining both technical options and economic perspectives.
- Seth Asked who will use the Targets methodology developed during the project.
- Jones 1) DOE for federal buildings,
2) ASHRAE/IES/AIA in the development of a performance path alternative within voluntary design standards,
3) the design office, to provide voluntary energy (cost) guidelines for the design processes.
- Winkelman Only 10% of architects use energy analysis tools at the present time.
- All The attendees expressed a general concern that it may be difficult to get architects to use a tool, once it exists.
- Jones Responded that the intent of the project was twofold:
- to develop a tool that would be of sufficient value in the design process that it would generate interest in its use, and
 - to be sure that a usable analysis methodology is available when energy cost, energy availability, or regulatory pressure again provides motivation for its use
- Hittle You should not underestimate the **IMPORTANCE OF PROVIDING BUILT-IN GUIDANCE** (imbedded design expertise and analysis input help) to the users of the Targets methodology. It will be necessary to avoid many of the mistakes commonly made in using simulation tools and in interpreting their results. Much of the number crunching, and frustration that normally occurs in the beginning could be avoided by providing guidance within the program (internal expertise--flags, prompts, help screens, etc.) based on a thorough, experienced understanding of the analysis procedure and the issues involved.
- Is the intent of the energy model development simply to correct the deficiencies of existing simulation tools to the extent necessary to demonstrate the Targets methodology?
- Jones Yes. But a second part of the effort is to develop a Targets methodology shell that will interface with a variety of existing and future energy models.

AFTERNOON:

The Monday afternoon session began with Jerry Jones asking the workshop attendees to briefly describe the simulation programs that they are most familiar with to handle the climate data for loads calculation.

- Schwedler Trace uses one day of climate data per month with four occupancy patterns. Two cycles through the day for warmup, then Sunday, Monday, Tuesday, and Saturday. Thus calculates for six days (repeating the same climate parameters for each day), with output for four days. This results in calculating 72 days/yr instead of 365, a factor of 5 reduction in loads calculation. System and equipment performance are analyzed for only

4 days per month, for a total of 48 per analysis. The overall time savings is therefore more like a factor of seven and the systems calculations are more complex and time consuming than the loads.

Hall The Carrier hourly program uses a similar approach.

Fireovid The ASEAM program uses CLTD, values corrected for UAΔT, CLF, and so forth to generate daily profiles. It then defines average temperatures for occupied and unoccupied periods to use with bin data.

A discussion of how to handle the climate data followed.

Hittle Dave Lowe (IBM) defined clusters of 6-7 day types for number of climates to reduce the number of calculations required. The procedure Lowe developed gave results that applied only for specific building types.

Barnaby Even getting decent weather files for the 8760-hour program will cost money. There is a lot of boring, grunt work still to be done. It is not being done now, but it must be done before the Targets methodology can hope to be successful. Further, the data needs to be tended, once done. The stuff that is there now is not being evaluated, e.g., there are 2 Oct 29th's on one file; we need to worry about finding and correcting errors.

All There is no difficulty in using a compacted climate approach (something considerably less than 365 days to represent a year). The approaches used by both Trane and Carrier would provide satisfactory results for most of the Targets methodology applications (clearly o.k. for the target setting and design analysis modes and possibly for the final evaluation mode as well).

At this point the discussion shifted back to the more general issue of the capabilities required of the energy model.

Barnaby You need a robust model that will handle full range of buildings and systems, including consideration of building thermal mass effects and the dynamics of thermal storage systems, if the designer wishes to do so.

Schedler There are two types of thermal mass delays:

- time for external loads to get to space
- time to reach AC equipment.

Don't forget the thermal mass associated with ordinary systems--chilled water for example. You need to examine thermal storage options early in the design process. 80-90% of cost decisions are made by the design concept stage. If the design is beyond that, there is no way to adjust the budget for other options.

Hittle Data management a key issue. Get a software specialist (a programming genius, "a hacker who really knows what he is doing") to work this out. But do not back off from quality of calculations. Microcomputer technology is progressing wildly faster than past expectations. Thus, even a conservative projection for the future indicates that very fast machines will be available.

Seth Need to apply the technology that exists. There are some 23 programs in active use. Need to allow people to continue to use those programs.

Hittle Options are:

- CLTDs with temperature bins or typical day profiles
- weighting factor
- heat balance.

The format of the hourly simulation, the number of hours (e.g., 8760 or 4 days/mo, etc.) is not the real issue. The issue is data baggage (the input and, particularly, the output) that you have to carry around. How do you manage the data? How do you provide the data to the user in a useful way? Choose one approach and go with it.

Jones That is the point of the meeting, to get input from you as to which we should choose.

Hall Got loads calculated. Now, what are you going to do about systems?

The discussion at this point turned to system and equipment simulation issues.

Schwedler Systems simulation is time consuming, equipment/plant simulations are much faster.

Jones What level of detail is needed in the system simulation? How carefully should control action and systems components, the coil, for example, be modeled? Can we get away with approximate models? Can we avoid iterating between the space loads and air-side system to get energy and moisture balances?

Hittle Options:

- Calculate the loads at constant room temperature (DOE-2) assuming the coil will meet the sensible and latent loads on the space. No iteration is required in this case.
- Calculate space and systems loads together (this is a more rigorous and more time consuming process. It may require some iteration (NBSLD does this, as does Trane).

Winkelman Some money should be set aside for updating the systems simulation procedures in the energy Targets project.

Hall The industry is adopting new control procedures, using electronic controls. These can provide new options--optimum start/stop control, anticipatory control. This is happening now. Just imagine what will happen in the next five years.

The discussion turned to the fact that the public domain programs were not sufficiently flexible to accommodate new control strategies.

Jones What do we do about equipment simulation, from coils to compressors? How do we define an analysis structure that will accommodate equipment that does not exist yet? Carrier and Trane use different approaches for presenting equipment data--they use different curve fit formulations for compressors for example--how do we structure the simulation to accept either set as input? What level of detail do we need to go to simulate coil performance, condensers, cooling towers and so forth? What items are important?

Schwedler There will be just a few curves for each class of equipment. Generic curves are fine for early design stages. For final evaluation, within families of equipment, usually you will have more specific data--COPs, part-load performance, etc.

The Monday afternoon session concluded at this point with the intent of continuing the discussion of systems and equipment simulation Tuesday morning.

TUESDAY MORNING 3/15/88:

The session began with a further exploration of issues related to systems and equipment simulations.

Jones What are Trane and Carrier doing with their programs? How flexible are the systems/equipment options? Are they modular?

Schwedler Trane is porting Trace onto PCs. There will be a modular system version, but we are very worried about providing it to users. We think users can really run into major problems if they do not know what they are doing in putting the systems together (e.g., the placement of an auxiliary coil can radically change psychrometrics). Trane will provide 28 'hardwired' systems that match most of what people want.

BTAC in England has, and Trace will, use graphics to show psychrometrics data at each point in the system. Trace iterates to define the coil latent load.

Jones What level of detail is really necessary to model the coil latent load capacity?

Schwedler Trane has looked very carefully at the impact of the iterations on the results of the simulation analyses. It increases the time considerably. However, there are new controls in use today that were not used 5 years ago. There are a lot of industrial environments being designed that need to be controlled within very narrow bands of temperature and humidity.

Winkelman The DOE-2 systems are very similar to the packaged systems in Trace. There are 25 to 30 systems available. Auto-sizing is an option in DOE-2--peak air flows from loads are used to size the system. Or the user can specify sizes. A modular system was carried through conceptual development earlier, but not finished. It was too easy for a user to "bomb." The program is now being modified so that the system can be changed using pseudo-code. Any modular-based system approach would need graphic displays of psychrometric processes to avoid problems and verify what you have done is what you want and not a Frankenstein model.

Question to Schwedler: Has Trane compared results from the modular system analysis with those from packaged systems that are equivalent?

Schwedler Whether or not a component system approach is used depends on nature of the design team, on the design team structure. Also on the construction approach. With design-build, you can expect to see a more detailed design earlier in the process.

Winkelman DOE-2 users are getting more sophisticated, they are asking for a component-based systems option.

Schwedler Trane has had only one customer in my recent memory that could not model a system he wanted to design with the current version of Trace. However, I would have no hesitation giving a component-based simulator to a sophisticated client such as the one that asked.

A discussion of run time problems followed.

Winkelman Would like ability to do 1-minute time steps, but wouldn't want to do that for all 8760 hours in all cases.

Barnaby Likewise, want the ability to select an iterative solution. Sometimes it is the best, and fastest, way to solve the problem at hand. Use what works.

There was some discussion of system sizing procedures.

Rule at BSG. Never let DOE-2 auto-size anything! Rather, size by a user defined procedure. Otherwise, you may get some very quirky solutions.

Winkelman Agree that great caution is necessary when using DOE-2 auto-sizing. However all you need to do is look at hours of loads unmet to spot problems; the procedure is well documented. The question really is What procedure should a user use for sizing? A design day, design week, use overcast days, use no heat from lights, etc., etc., etc. There is no ASHRAE standard procedure.

Barnaby Taking annual loads as basis for sizing should be exception rather than the rule.

Returning to a more general discussion of systems:

Hittle BLAST uses a number of set system descriptions, but each system set calls the same set of subroutines. There is no duplication of the code elements. The BLAST coil model is based on ARI standard. It provides coil loads (with no iteration), when user specifies the coil output conditions. There are some users that the BLAST procedure does not satisfy (e.g., Hittle). This type user will substitute their own simulation code when necessary.

Users interested in the details of HVAC system control probably should not use an hourly annual energy analysis tool. They need to examine a smaller time step. However, for most users the assumption that the system operates in steady state on an hourly time step is fine. It is probably fine for Targets purposes.

Barnaby A user must be able to get detailed hourly numerical data for specified periods, to check what is going on internally. BSG uses this data to check the simulation. It is a must for trust and for debugging.

Fireovid In ASEAM the systems analysis follows the DOE-2 procedure but imposed some limitations on dynamics. Without the ability to define floating temperatures, one must assume that space setpoint conditions are being maintained.

ASEAM tracks the psychrometric properties throughout the analysis. This provides a good educational tool as well as a reality check on the analysis.

Winkelman Definition of the systems process with diagrams of the system and property definition are very important from an educational point of view.

The discussion shifted back to more general project considerations at this point.

Barnaby I see four tasks here:

1. defining an energy analysis 'engine';
2. defining the analysis process;
3. defining the user interface;
4. and providing the user with some expert guidance.

All these tasks are difficult. Some of us have been working on just one of these areas for 10 years. Do you have the time, money and expertise resources to accomplish this? Seems like a way to spend a lot of money without a specific objective in mind.

Jones The fact that it may be difficult to accomplish all this is recognized. However, the job will never be done if it is never started. The task here is to break the problem up into manageable tasks and get started. That is why we are so anxious to use existing simulation 'engines,' to avoid all the pain of starting that process over.

Seth The user interface is very important. You must think of several concepts to test. You must develop multiple prototypes, get users to test them, and have them tested and tested and tested. The idea of a prototype like "Steamer," for example, seems exciting to us as experienced people, but may not be exciting to most users.

Busch The output may be a more serious user interface issue than the input. You must open up the energy programs so they are more accessible to users. We have a more difficult and complex process to display than the "Steamer" example, and much of what we want to see can come only from a parametric analysis. This means there will be a lot of output to consider. Most programs have an easy access to input via common blocks, but there is not so much standardization of the output. The output presents a much more difficult problem, given the state of the art.

Seth In terms of expert guidance, it may be dangerous to give a designer so much input that he would give up his own judgment.

Busch "Expertise" is needed to minimize the mistakes made in the use of the programs, not to minimize design mistakes.

Winkelman How would user get started in a system like this? With a tutorial?

Busch One may need to walk a user through an actual design problem. Perhaps imbedded HELP messages could be used.

Barnaby Some of this problem can be viewed as a STANDARD SETTING PROCESS for file structures for energy simulation programs. Bruce Novell is a good point of contact. Others that might provide information are

- AutoCAD to interface Carrier - Jim Hall
- Scribe to Seri RES - ?
- Intergraph to BLAST - Dwight Berenak
- AutoCAD to BESA - Dan Seth.

There is some likelihood that Carrier and Trane would be interested in a common data file transfer format.

Hittle Just remember, with all this built-in help you will need shortcuts so that an experienced users can bypass the interactive help. He will get very impatient if he can't.

Jerry attempted to solicit some summary comments on the current status of the programs that should be considered.

Jones You have told us that we should choose a specific program and use it, making only minimum modifications, as the "engine" for the Targets model. Which of the available public domain programs would be the best choice?

Winkelman DOE-2.1D is the most up-to-date. It has a more flexible systems input format and more possibilities on systems controls. It will also allow analysis of desiccant cooling and CBS ICE will be included. D is moving more towards a component-based analysis.

Hittle BLAST, Version 3 is the latest modification. Pedersen and Univ of Illinois are maintaining the support. It is up to ANSI Fortran 77 standards, and is portable under UNIX. Pedersen is working on adapting BLAST to run on a Macintosh. He has been partially successful. LCC is now a separate module. The manual has been redone. It now has an interactive data prep module, BTEXT, that provides input and prompter for neophytes. It includes an ice storage module taken from Wisconsin.

2.2 Consultant Comments

The consultants were asked to spend the afternoon of the second day writing up their comments and suggestions. The comments are presented here, essentially as they were written, to preserve each writer's original intent.

Comments by Dan Seth

- The energy targets methodology should be designed to address a variety of user types including architects, engineers, and code officials, taking into consideration their level of sophistication, i.e., novice to expert.
- The methodology should be broken down by the stage of analysis; i.e., preliminary target, detailed analysis of the final evaluation.
 - Each time a user selects a particular stage of analysis, the program will advise the user of information requirements to perform the analysis along with the areas to avoid.
 - Give the user the option of using a fast-track analysis so that an experienced user does not end up wasting valuable time stepping through the analysis package.
- Extensive on-line help should be an important feature of the methodology. On-line help could be in the form of graphical explanations, dates, or simple instructions.

- The user shell should be generic in design so that other programs, be they proprietary or public domain, can be interfaced with the shell, provided they meet certain criteria. These criteria should be made available to all software developers to help them in assessing whether their particular program qualifies for an interface.
- Speed of execution and user friendliness are accorded the highest priority in any software design.
- The user shell should be flexible and modular so that future software compatibilities can be added as they mature without disturbing the effectiveness of the shell.
- The analysis core energy simulation methods that are interfaced with the user shell must have the capability to address from very simple to very complex analyses of HVAC and lighting systems analysis for a variety of building types.
- An hourly time step is the shortest time step necessary to carry out design simulations and performance simulations. At the present time there is no need to break hours down into intervals of shorter time steps, as much more development is required in the system controls algorithms development to simulate EMCS strategies.
- Two separate user advisory groups should be established to guide the development of the Targets methodology:
 - one consisting of experienced architects and engineers
 - one consisting of novice architects and engineers.

A steering committee should review all user needs and assign priorities as necessary within the constraints of available funds.

Comments by Jim Pegues

The following notes consist of consensus agreements, comments, and suggestions regarding the various topics discussed during this workshop.

Load Calculations

- Fundamental, thermodynamic, and heat transfer laws should form the basis of energy simulation work; heat balance and weighting factor methods are good candidates for that basis.
- A fundamental basis minimizes assumptions; approximations, in turn, minimize possible application and accuracy problems.
- Hourly time steps, 8760 hours/year, should be used in the simulations.
- Thermal capacitance effects are an essential consideration.
- Flexibility is an important need when applying load calculation methods for target setting, design, and evaluation stages.
- Inputs and calculations in target setting and design stages must not be too demanding as the effectiveness of an iterative approach will be reduced.

- It may be useful to permit simulation on varying levels of complexity to suit different applications.

System and Equipment Simulations

- A comprehensive range of component models should be offered.
- A components model approach would be useful on either a programming or user input level, or both.
- On the programming level, the component approach minimizes code size and complexity and consistency problems.
- On the user level, a component approach lends itself to creative uses and applications with microprocessor controls.

Definition of Target Users

- The target user group must be carefully defined and their needs carefully assessed.
- Depending on how low the target group extends, this may seriously affect or restrict some modeling and design approaches.

User Interface (Input, Output, Operation)

It appears that several modes of input would be useful, both for the varying needs of the target/design/evaluation stages and for different users as well. These input modes might include

- CADD interface, for evaluation stage
- "sketch"-type CADD interface for target/design stages when detail is not required and speed is essential
- menu and prompt input, for advanced users
- text file editor, for advanced users.
- Attention to defaults and organizing input is essential.
- A complex, comprehensive analysis requires a large quantity of detailed input. This can be overwhelming and an obstacle during program use. Use of defaults and organizing inputs can overcome these obstacles, as long as it does not impair accuracy.
- Other obstacles in complexity include
 - Designing for complex, far-ranging use adds overhead to the effort required for basic designs.
 - One- and two-zone jobs far outnumber complex, multiple-zone jobs. Yet, a sophisticated tool that handles complex jobs may be difficult to use for simple jobs unless it is carefully designed.
- Along these lines, there is often a need for direct, focused tools in the design process. A multifaceted tool, whose uses range from targeting and design to research, is often not effective for basic, focused tasks, unless carefully segmented and organized.

- The ability to easily perform parametric studies in the design stage is very important.
- Outputs in various forms, from tabular to graphic, are required.
- As with inputs, careful organization and presentation of output options is necessary, otherwise, the quantity of output information will be overwhelming.
- Most users will typically be interested in simple, direct output; this includes bottom line results in both graphic and tabular form.
- Output of intermediate detail is next in importance.
- Availability of extreme detail is necessary for trouble-shooting and research purposes.

Comments by Fred Winkelman

Question: Can the name of the project be changed to emphasize the fact that the goal is to develop a process rather than simply to calculate numerical targets?

The project is worthwhile, necessary, and timely. It should raise the consciousness of the design profession and increase the ease of achieving energy-efficient buildings.

Related Efforts

- Try to get a demonstration for the Targets development team of A-TAS and B-TAS developed by Amazon Computers in England (I have the phone number).
- A-TAS allows user to interactively/graphically develop architectural input using a digitizing tablet or cursor (similar to BSG's CALPAS front end). It displays a three-dimensional wire frame view from the outside of a building. A-TAS also has the ability to rotate the building position. Other displays include
 - color renderings for different sun positions
 - an interior "walk-through."
- B-TAS uses A-TAS database to calculate loads (hourly), then systems and plant. Systems are component-based; the user arranges icons (fans, coils, controllers, thermal states, etc.) on screen and connects them (in a fairly arbitrary fashion), then the program does an hourly iterative solution. The plant is also component-based. Output displays from the systems plant include hourly profiles, the psychometrics chart, and the multiple run comparisons.
- This is the best simulation program I've seen. It should provide many ideas concerning possibilities and limitations. But it's proprietary, and Amazon wants to enter the U.S. market, so getting the source code itself will be problematic as it currently runs on Apollo.
- Joe Clarke (ABACUS) and Damian Mackandal (Rutherford Appleton) are working on the Intelligent Front End (IFE) in the United Kingdom. The ESP is the simulation engine. The most interesting parts are the front end and the output processor. The front end will hold a dialogue with the user using terminology tailored to different professions (i.e., architect, engineer, code officials) and

purposes of simulation (annual energy code, comfort code, sizing, economic analysis, etc.). Reports produced by IFE are selected automatically depending on type of analysis, thus providing an "intelligent" choice of information to be assessed by the user. The whole thing is driven by UNIX shell scripts, which avoids extensive software development and allows rapid prototyping modification and extension. The shell script approach could, of course, be used with other simulations.

- Energy Kernel System (EKS) is an investigation of advanced interfaces. I have proposals (from United Kingdom) for this. The idea is that the EKS should be able to build interfaces as well as calculation programs. Some of the ideas, approaches, and (perhaps) early prototypes may be useful for the Targets project.

Simulation Engine, Sources of Expertise

- BLAST versus DOE-2 as the choice for the initial engine--Bruce Birdsall has used both programs extensively and can give a relatively unbiased assessment of the pros and cons. (Since the projects Bruce works on are partly funded by DOE, CERL, EPRI, and others, he tends to not have a financially influenced bias in favor of either program and so I felt comfortable recommending him for his opinion.) Bruce has also run simplified methods (Trackload, LoadShaper, ASEAM 2) and can give recommendations on the relative merits of detailed bin methods versus modified degree-day methods, etc. Another person who is very qualified and who should not be biased is Ed Sowell. He has used BLAST extensively and has developed an input booklet for the program. Ed Sowell has made many DOE-2 runs and has a good feeling for the differences in loads due to hourly heat balance, BLAST versus the custom weighting factor DOE-2 approach.

User Interface

- User interface includes a library of space functions and space geometries. It is easy for a user to assemble a building from library elements, but try to avoid "input from scratch" as much as possible.
- Have a library from which choices can be made and schematics displayed, then allow user to select options (with mouse) and set operating conditions. Again, avoid input from scratch.
- For component-based systems, allow for graphical/interactive choice and the linking of components. Have a "consistency checking" to flag nonphysical or unrealistic configurations (e.g., fan put in backward or drybulb thermostat connected to humidifier controller). Visually display the operation of the system hour-by-hour with color, numerical, or symbolic indication of temperature, flow, humidity ratio, outside air fraction, etc., at various points in the system.
- For a loads calculation, display (graphically) loaded components (solar gain, heat from lights, conduction, etc.) space by space on an hourly, monthly, and annual basis. This is a powerful way to pinpoint the source of high heating or cooling loads. Some intelligence could be embodied by having a shell detect big load components and suggest mitigation techniques. For architects, consider very detailed interior illuminance calculations so that impacts of window changes can be assessed visually.

Importance of Thermal Mass, Number of Simulation Days

- For thermal mass tests, run DOE-2 with a very low floor weight (i.e., low mass) and with custom weighting factors (i.e., with mass); compare the results for different space types and climates.
- For the number of simulation days, compare full-year DOE-2 simulations with 12 run periods of, say, one day per month or one week per month.

Interface to Proprietary Simulation Engines

- This is critical to gain support of E-20, Trace, etc. users who will, in turn, stimulate nonsimulation engineers to consider the Targets methodology. Make this an early priority for at least one proprietary program. This will also give a quick idea of what the problems will be and how to generate a fairly "neutral" neutral file. Zulfi Cumali has thought a lot about this. Perhaps IBPSA could assist in developing interface protocols. An important consideration would be how to handle program enhancements; e.g., would the component-based version of Trace (if we didn't already know about it) require massive changes to the interface?

Comments by Jim Hall

I view the Targets model as an information organizer that is continually updated as the design process progresses. It has output capabilities necessary to satisfy the needs of

- target setting - custom energy budgets, operating cost objectives, and lighting level calculations
- design analysis - load calculations for terminal and equipment sizing energy analysis for system and component selection
- final evaluation - life-cycle costing, documentation of control strategies and sequences, and plant schemes.

Default criteria are established for given client/project requirements. This information will guide the user but must be supplemented and updated as the project progresses.

The Targets model must not be simply a DOE/BLAST preprocessor. It should only organize input and output in a manner that is accessible to the users of various analysis programs. The user will then edit the data for a specific program, run the program, pass the results to downstream applications, and finally to the target presentation manager.

The depth of the analysis should only be a function of the designer's needs. While the program may have the capability to handle very complex buildings, the user should be able to bypass information or functions that are not necessary at a given point in the process.

Comments by Chip Barnaby

I recommend breaking off manageable pieces of the project and approaching them separately. The results of these efforts can then serve to better define the whole.

- Define the target selection and use process, ignoring the user interface question. Use DOE-2 or BLAST and reduce the current general proposals to a prototype-specific target process.
- Generate prototype user interface models and begin to test them with users.

Develop expert systems techniques for intelligently defining the defaults required for early studies. Again, this problem can be approached without much consideration of the user interface or targets process.

Define explicit file formats for data transmission between modules.

Write a portable code. Isolate all functions that will be system-dependent such as I/O, graphics, operating system access.

Identify general functional requirements early and write all codes to those specifications. Error-handling is one area that is difficult to retrofit into a program. Another is multiple unit systems (IP and SI). Decide early how these issues are to be addressed.

Do not decide that specific issues are unimportant because they often do matter. Thermal mass, to pick an example at random, often has little effect, but modules that ignore it will be seriously in error in certain cases (pick up loads, for example).

This project is, by design, an answer in search of a problem. The idea is to be better prepared at leading the next round of standards enhancement. Since that round has yet to begin, a certain amount of "missing the point" is to be expected. Therefore, you must develop everything from the "tool kit" point of view: everything easily changed, easily reorganized.

Comments by Jim Fireovid

I suggest using DOE-2 as the final hourly simulation. However, it may be useful to test the concept or methodology with a simplified tool (e.g., ASEAM 2). On the conceptual stage it would be much easier to hook into ASEAM 2 than DOE-2 and make changes, test, etc.

In order to be successful, the simulation program used (BLAST or DOE-2) is much less important than the design of the input and output shells. Users will need a lot of help in entering the data and in interpreting the results. I feel most of your efforts should be in the design of the input/output.

I am not sure of the usefulness of extensive and rigorous calculations in the predesign steps. At this time, almost all of the inputs are defaulted, making rigorous calculations less meaningful.

Perhaps what is needed is an expert systems approach to help optimize the initial design approach. Energy calculations can only tell us of the Btu consequences of our input assumptions. If an expert system could help us make rational decisions to start with, we could optimize the design much earlier (A/E's do not [or will not] spend a great deal of time in this optimization process).

I think you must stress the hooks into all simulation software. Developing a PC DOE-2 version with a very extensive front end and back end (input/output) may not be perceived very well by the makers of competitive products.

You have a difficult task just due to the rapidly changing PC environment. By the time you get a prototype working, your compilers, computers, etc. may be out of date. What are you going to provide for the users who don't upgrade to 386 technology? Windowing software--graphical displays--will be much more powerful in the near future. I think more progress needs to be made in the entire concept, i.e., predesign, targets, analysis, etc. How is this tool really going to be used (instead of any other software/hardware issues) at this time?

I feel that the intended users of this methodology are much less sophisticated and knowledgeable than you perceive. Will we be developing tools that are truly useful only for a select few? For example, how many DOE-2 users have simulated daylighting? thermal storage? complicated rate structures? We may know how to do this, but I doubt if the average A/E would.

Perhaps your next step is to get a typical A/E's opinion of what is needed. It seems you may be trying to second-guess what the A/E market will want or use. More marketing research (i.e., BESA) could be beneficial at this time.

I think most of your efforts should be conceptual. This does not seem to be a technology problem (as far as energy calculations), but rather an issue asking

- how this tool is to be used (input/output)
- how it could be used to optimize a design
- what targets are
- how expert systems fit into the process
- how we can best present a meaningful output
- what variables can be optimized.

These are questions for the typical users (not experienced persons such as those in this group). I would suspect that few of the group here have gone through predesign or optimization analyses. (I suspect that architects now do this in a vacuum and give their designs to the engineers.) Somehow the energy calculations must be introduced earlier in the design.

Comments by Bob Busch

Major focus must be placed on the user interface:

- Input
 - will reduce energy analysis intimidation
 - will minimize errors or mistakes (helpful if some experts identify those parameters with major impact on energy models and on energy use)
 - should be graphical/figure/picture-oriented
 - should have an available menu selection with ability to text edit and/or skip large portions of input requirements.
- Output should include features such as
 - definite graphics with major statistical information (mean, standard deviation, correlation coefficient, etc.)
 - plots of one variable vs. another
 - the ability to look at trends, derivatives, etc.

- direction/guidance on parametrics; parametric selection, ranges of values, etc. This is particularly important during the design analysis process
- the ability to allow for user intervention and direction.

The selection of the engine should be done as rigorously as possible, and be based on first principles. I would prefer heat balance over the weighting factor. It should be an hourly simulation with the ability to do 8,760-hour design periods. Memory requirements can be traded against speed, so execution times of 10 to 30 seconds are probably realistic in 3 to 5 years. If pushed, I would select DOE-2 over BLAST because of daylighting capabilities and newness of current version. However, the DOE version must incorporate variable temperature into loads.

BLAST probably has better systems and provides more options, but these are not as important to the user community as the lighting features. Daylighting "on the side" will not be sufficient for the user community.

Expert systems will become vital when introducing energy analysis programs to new audiences. We need to get Bruce Birdsall and some equivalent person from BLAST to provide input into an expert system that describes how to get the program to model something that's like a predefined system but isn't quite there. Expert systems could provide guidance on rules from the building location and building type. For example, which things should be considered when building a specific type of structure on a specific location?

Three different audiences--architectural, mechanical, and lighting--require different focus during the design phase. We need to have some standard default packages to allow parametrics to be run specifically for the

- envelope (default lighting and mechanical system)
- system (default envelope and lighting)
- lighting (default envelope and mechanical system).

The Targets methodology should provide direction to the designers without requiring much input or knowledge of actual building features.

Comments by Mick Schwedler

If the methodology does not, at its inception, interface with the engines being used by the potential customers, those customers will state that they cannot afford to switch engines.

If design professionals are being innovative and designing energy-efficient buildings today, don't add a hurdle to their design process.

Choose an engine that is not limited in the control strategies. Those strategies will increase dramatically in the future.

Many times, voluntary standards become nonvoluntary very quickly. Suggest that if they are to be voluntary, a better phrase should be used to describe them.

Help novices, but don't impede experts.

Don't sacrifice a good product for time's sake.

From your description of funding, an expert system will be hard to include, but expertise embedded in the shell must be flexible enough to allow the user to be able to use the advantages of other engines, i.e., any expertise embedded cannot depend on the chosen engine.

Make sure you understand the way design professionals' processes work. While not necessarily following it exactly, the methodology will be much more accepted if it is somewhat familiar.

Beware of file and data limitations in the microcomputer environment.

Before talking with designers, make an estimate of the amount of time this procedure will take and ask the designers how much time will be acceptable. You may be surprised at the result. Also ask how much time it would take if they could get paid for it, and what the acceptable rate of pay would be. DOE should be willing to pay for the work.

The bottom line is to make sure designers are helped, not hindered.

3.0 Building Cost Workshop

In determining how best to develop and integrate a building cost model into the Targets model, the project team enlisted the help of five experts in the field of building costing. The invited experts met with members of the project team in a workshop setting in Washington, D.C., on May 17-18, 1988. The minutes of that workshop are reproduced in Section 3.1. The written comments summarizing each consultant's recommendations and ideas are presented in Section 3.2. Joseph J. Deringer and Jay D. Hall compiled the summary of this workshop.

3.1 Workshop Minutes

The building cost estimating consultants who participated in this workshop were

Bob Gair, R. S. Means
Bob Morse, CRS Serrine
Jim McFall, McFall, Konkel, Kimball
Al Paxton, Marshall Swift
Ken Sigel, Wolf & Company

Targets project team representatives included the following individuals:

Joe Deringer, The Deringer Group
Carol Gardner, U.S. Department of Energy
Don Anderson, Burt Hill Kosar Rittelmann Associates
Brian Johnson, Pacific Northwest Laboratory
Rob Briggs, Pacific Northwest Laboratory

TUESDAY, MAY 17, 1988

DISCUSSION OF GOALS AND OBJECTIVES:

Paxton: Is it expected that all of the proposed features of this program will fit into a conventional desktop computer with only 40 Megabytes of hard disk storage?

Deringer: Not likely. Probably the program will require a computer with a processor which is faster than today's best processing chip (e.g., a 80486 chip), with 4 to 8 Megabytes of RAM, and 200 Megabytes of hard disk storage.

DISCUSSION OF USER INTERFACE SLIDES

Slide: Overall Targets Project

Morse: Is this all for a "will" or a "should" cost basis?

Deringer: "Should" cost.

[Note: temporarily about this, as the following indicates.]

Morse: Then you are being inconsistent.

[Note: Morse is using specific language from federal construction practice, without indicating specifically the source. Deringer misunderstood the intent, and some confusion arose, but definitions were made and the confusion resolved. "Should" costs are defined by federal agencies prior to releasing a project to an A/E firm to design. The design team then develops "will" costs, that the design will cost when constructed, in progressively greater detail, as the design process continues.]

Sigel: Federal agencies planning a project start with historical first cost data as a basis for estimating the cost of the current project. This is used in developing a programming upper limit restriction on energy consumption. Then there are several line item adjustments allowed (area, time, etc.). This limiting cost is a should cost which cannot be exceeded at any later time in the design process. Thus, federal buildings must comply with federally mandated requirements, which are very strict. A feasibility analysis, before any design, is used to determine overall costs before the project can proceed.

Deringer: Several cost approaches are to be provided in the Targets model.

Morse: The iterative capability desired will require very powerful expert system capabilities which will not fit in a PC.

Paxton: We have all of the pieces, but the sequential process will vary for different types of clients.

[Note: Provide copies of the Targets model information flow to the consultants.]

Paxton: Are you aware of possible copyright infringements?

[Note: There should be a strong distinction in the demo between the programming figures (Joe's figures), and the later stages of design (Hayden's figures).]

Morse: The demo screens are too cluttered.

Paxton: The model should include all building costs. Ultimately, the component costs will affect the life-cycle costs. Some designers steal from other component budgets to pay for specially desired energy features of a building that wouldn't otherwise fit into the budget.

Sigel: When the scope is not fully defined. An automated cost database/estimating procedure can miss the mark badly.

Paxton: A theoretical cost estimate (database derived) need many adjustments or reality factors.

Morse: You need to initially establish the acceptable cost, before design. The arch/eng does not do this. And you can't make a cost estimator a designer. This is usually based on historical data and completed in a budget/feasibility mode. The next two phases are design and construction. There are serious discontinuities between each of these phases. Once you leave one phase, you cannot go back. Once the budget is established, it is very unusual to change it.

McFall: This approach moves energy design decisions up earlier in the design process. This will likely involve changes in who actually makes the decisions.

Deringer: The detail is not likely to show up this early in the design process. Designers can create their own customized databases.

Sigel: This is close to the real world process.

Morse: The major issue in this approach is the updating of the databases.

Paxton: What is the marketing hook? How do you prevent multiple inputs? There are several competitors on the cost side.

LUNCH

[Note: Active candid discussion took place during lunch.]

CONTINUED DISCUSSION OF THE TARGETS DEMO.

Paxton: Icons are good for the user but too slow for regular use. Consider a text editor approach if you would like to see the program accepted for general usage. The layered menus clutter the screen.

Deringer: This is a screen resolution issue. If the menus are small enough, then the menus will not look as cluttered.

Morse: The layout should be done in CAD. There should be an interface to several CAD programs.

Paxton: Is the actual input going to be done by clerical or the A/E? The A/E could prepare a form, which can be manually entered in a batch text input mode.

Sigel: You lose the educational/what-if capability if the work is done by clerical people. However, the A/E could come back after the initial data entry to play the what-if game.

Paxton: There should be at least two input modes: dummy, experienced.

DISCUSSION OF TARGET SETTING

Paxton: Chance for error is proportional to premature detailing of a building's components.

Deringer: In the early schematic phase, maybe as few as 100 design strategies/technologies may be considered in target setting mode.

Sigel: But it really depends on the type (complexity) of the building.

[Note: Discussion moved to the issue of the best measure of energy cost.]

Sigel: Establish a baseline, and then make comparisons to that baseline (i.e., payback analysis) to determine whether to consider energy options. Mobile [Division, Corps of Engineers] determines which energy options will pay back in less than 5 years. Options that qualify are incorporated in the design as "no-cost" items.

Deringer: Do we need to provide details for all defaults provided? How much detail is required?

- Morse: Historical databases are the best justification for defaults.
- Sigel: Problems with historical databases: What is the data source? Need to test databases with practical cases for problem areas.
- Deringer: Problems with internal database requiring updating regularly.
- Paxton: Updating of labor is easy. The problem is updating materials prices. The problem with materials costing is mainly the tremendous variety of components. Five quality levels should be used (poor, fair, average, etc.). A range of costs should be used, instead of a hard price. Marshall Swift has 193 models (?) for building costing, each for a different type of building quality.
- Sigel: The requirement for number of databases depends on the number of building types required.
- Deringer: Not building types. The approach we are taking is more at the level of space functions-- 30-40 may be required. Three levels of detail are being explored:
- building
 - building space function
 - thermal zone.
- We are also looking at a fourth level, task areas, in case they may be needed.
- Paxton: It is tricky to use defaults. You have to back out when options are considered. Double counting is very often buried. An alternative is to provide costs at the level of detail of shell cost, lighting cost.
- Deringer: Total first cost of baseline building (e.g., \$140/ft²). For energy related schematic design, we need documentation for the origin of the cost number. Changes from baseline will be input by the user, in order to customize the database.
- Morse: To accommodate user concerns, allow the users to develop the costs by themselves, which can be compared to defaults. The answer by both methods should give the same price. The availability of the method satisfies the user.
- Paxton: For modest penetration of the A/E market, provide a template. For more thorough penetration, provide the actual data. The data is provided by other retail sources. Fundamentally, what is desired is a macro cost estimating method which also provides energy performance considerations.
- Deringer: It is not an either/or issue. Both the data and the customization procedures appear to be required.
- Paxton: The template tool really mainly involves an editing utility. A Lotus based template has been attempted by several retail firms. Only the very large firm would use templates, because only they have the staff to input and maintain the data.
- Deringer: There are three current methods of evaluating compliance with building energy codes. Is this approach feasible for cost estimating. Templates would most likely be reformatted by several of the large organizations. This is likely to be a possible source of confusion.

BREAK

Gair: The software linkage between the model and standard databases is a major hurdle that should not be underestimated.

Deringer: We can only use software as an integral component of Targets which is in the public domain. However, the linkages to proprietary databases can be provided as part of the Targets model.

People at the national labs can prepare the list of missing database information.

Sigel: The majority of the HVAC systems options are not available in available databases. Must also consider regional issues: availability, etc.

Deringer: We may not put in all items in the database. A customization utility must be provided for designers to put in their own favorite design solutions.

Paxton: We should consider publishing an RFP with all of the energy options that we want to have cost data for.

Sigel: Who designs the options before the cost estimators do their thing? Use ASHRAE people to develop designs for various energy options.

Paxton: The final product must have the capability to readily incorporate new products and customized designs.

Morse: The design analysis side level of detailed costing can be used to form a database of generalized costs which can be used in early schematic design. This database is customized for the user, with detailed explanations of the path to achieve the overall cost info.

BREAK

Deringer: Discussion of tomorrow's session.

GENERAL COMMENTS

Paxton: We need to crystalize the needs of the cost model before things can proceed. The approach at the conceptual level is similar to the approach used for assessor's needs. Although this is not necessarily what the designers think that they want, it is exactly what they are currently doing. Total time to be spent to complete the building cost model looks like about \$200 K (at least).

Sigel: An approach to simplify the model is to be very selective about what is initially completed for the Targets model. By limiting the initial development efforts, a workable approach can be developed.

Paxton: Lotus took 200 man-years to develop.

Gair: It has been published that forty percent of spreadsheets have errors. These are very difficult to uncover, and most go unnoticed. This is an important consideration for a development plan for templates.

ADJOURN

WEDNESDAY, MAY 18, 1988

GENERAL COMMENTS ON PREVIOUS MEETING DAY

- Morse: Must design around needs of design community. Three-phase implementation would be beneficial to all: early effort, interim effort, final working system. This will help the design community to become more aware of what is going on. Software demonstrations at trade shows is a good communication opportunity.
- Deringer: The project has set up a formal review process within three professional organizations: ASHRAE, AIA, IES.
- Anderson: The problem with databases is maintenance. Work with general square foot costs. Templates provide a means of accessing the data without the maintenance problems.
- McFall: The tool seems to be for experienced users, not newcomers. There are credibility problems with users--most engineers are very skeptical of tools.

Major design problems in the industry are:

Indoor air quality
Humidity control
Evaporative cooling
Passive solar
Nighttime cooling

More psychrometrics will be required than is presently available in most tools. The margin for sizing has been too tight--this is also changing. People are demanding that margin be put back into design.

How to compare models to reality--emphasis should be comparative modeling.

Much of the success of the Targets model will be to address these current needs. Testing of the model will also improve its credibility.

- Gair: The practical side of the proposed model, the functionality of the tool will improve its acceptability. Primary issue is to provide a resource to get energy costs. If the design community wants more detail, then find out what they want, and provide it in an acceptable manner. The end user will be required to take the project along into deeper levels of costing. From the O&M perspective, need detailed costs. But detailed cost in other areas will provide more areas for criticism. Walk before you run.
- Paxton: We need a very macro approach. We don't want the designer to focus on costs--the focus is intended to be energy. If you provide too much detail, it will be a great distraction. The initial estimate is only a conceptual baseline from which to make energy decisions. The renewability of the database should be field-tested. Ask the audience what they feel comfortable with. The update cycle should be under two years--especially for labor.
- Sigel: A/Es are often mostly concerned with the bottom line--dollars. They only want to meet the budget and end up with an operational building. Energy codes are used to establish the minimum level of spending that they can get away with.

The exception is owner/user. They are the ones who watch energy. They are the ones that this Targets model should be targeted as the audience.

Johnson: The provision of customized databases is very important. Most designers are currently using their own historical databases already. The cost info in a Targets cost database should be limited to square foot costs for component assemblies.

Briggs: There are important issues that are significantly different when you think about each of the different operation modes for the model. Yesterday, the focus was mostly design analysis. In the context of target setting, we really only need a few generalizations about costs. This is a difficult task--to shift gears from the global possibilities to a subset of useful options. The issue of copyright restrictions on the use of data in existing databases needs to be addressed.

Paxton/Gair: We don't know the copyright restrictions either.

Deringer: Some of the high tech options that could be used to test the concept of dealing with innovation could include

- ice storage HVAC
- variable transmissivity glass
- daylighting and occupancy sensors.

The consideration of these high tech options provides methods for users to install their own options. Thus, it is not as important to wisely choose these high tech options as it is to establish these methods/procedures to include them.

McFall: The technologies must include the well established options (options that have been around for more than ten years).

Anderson: The costing of new technologies varies significantly.

Sigel: It generally takes about 5 years for the people that are making bad estimates to leave/drop out of the market.

Paxton: A contradiction is that we want macro level costing for non-energy related building components and detailed cost info for certain energy-related building components.

Morse: A global perspective is important. The dichotomy that exists in the project team mirrors the dichotomy that will exist in the marketplace.

Sigel: Regarding liability--we are not representing that the costs are guaranteed. The customer is not paying for that service. Thus, we do not have a problem.

Paxton: You are simply selling published data, like several other organizations. There is no benefit/gain to us from the users through this estimating service.

Sigel: You need to develop a detailed strategy for costing methods for each specific area of interest. Also, most engineers are aware of basic building component costs. So we don't have to be afraid of providing opportunities to provide their own inputs. One bad experience is the basis of evaluating cost estimating procedures. After one bad experience, the designer returns to his old tried and true methods. The next step is to determine the structure of the

costing estimating procedure. What level of detail is required for each line item? This model is not for inexperienced designers. That would be like giving a child a loaded gun.

Deringer: We need to identify who our audience is for each stage of development. For example:

- federal: Corps of Engineers
- large corporation: IBM

We should contact these organizations and determine what their cost estimating procedures are.

Regarding detailing: for sophisticated users, when a problem occurs he insists on knowing the details.

BREAK

[Note: The five invited cost consultants spent from 11 until 1 pm developing their write-ups of recommendations and comments on the Targets building cost model. The recommendations and comments provided by each of the five invited consultants are included with these minutes.]

LUNCH

SUMMARY OF WRITTEN NOTES:

Sigel: The project team needs education in cost estimating.

A canned database is not likely to be accepted. A toggle switch can be used to access various existing databases.

Two levels of updating should be used--quick generalized updating, and detailed updating.

The level of detail should be proportional to the data is available.

Templates should be used to allow the designer to enter new and modification to the cost data when desired.

Morse: Another approach is to use a standardized template, that all data will be manually entered with.

Paxton: My ideas are 180 degrees to Morse's comments.

The productivity of this meeting has been hampered by the lack of a clear identification of the audience.

Packages can be identified. Costs for each item in the package can be listed. This is a spreadsheet (simple) level of detail.

If the option of updating individual prices of items in the package is desired from a database, then you are no longer talking of a simple program. The approach for this level of detail requires the development of a full blown database.

High tech mechanical systems should be developed by a national firm, or a possibly a team of 10 people across the country. This data is not currently available in existing databases.

Cost data for detailed design is not possible on a 720 Kbyte floppy database. It is unreasonable to think that detailed cost data can be developed and maintained within this project.

Morse: Would the cost database vendors be willing to reformat the data for the purposes of this program?

Deringer: The A/E market is less than 500 packages, if it is really good and cheap. Thus, it is unlikely that the cost database vendors will develop customized cost databases for the exclusive format demanded by a program such as this.

Sigel: Initially, the approach should be to enter 25 numbers to get the estimate that they want. The problem with any existing tools which do this, is that they do not format the data and total costs in a way that designers are comfortable with. The need quick access to see the origin of the cost data, and the ability to make changes as necessary.

Paxton: Are you talking of a square foot mechanical design estimating procedure, where the data is taken off a drawing? This cannot be done at the conceptual level.

Sigel: The cost estimating methods should closely follow the design process. Macro costs could be used for conceptual design. More detailed costs could be available for schematic design. Very detailed costs could be provided for detailed design.

[Note: For the purposes of the early development of this project, the conceptual and schematic design should be the main areas of effort.]

Sigel: The database should be structured distinctly differently from the interface to the database itself. The interface should model the designers costing process.

Gair: Who is the end user? Information should be solicited from some specialized segment of A/E firms (i.e., industrial building design firms).

McFall: The essence of the project is to determine how to break (exceed) the target, or not to break the target. If you break it ignorantly you've got a problem. If you are aware that you break the target, you can do something about it.

What can you provide that does not exist? I need to compare the numbers that I develop for a given project to other numbers from a reasonable number of baseline projects. How do my numbers rank with other similar projects? I have much more confidence in my own historical data than numbers from someone else's estimation method.

Morse: You need to better understand the breadth and diversity of the market, before a useful format for the target can be developed.

Final evaluation is a misnomer. It don't think that this is feasible within this project.

Ultimately, it is up to the user to develop their own databases. The best databases for a customer's needs are developed specifically for his needs. Only he can do this effectively.

It is important to make the user aware of the limitations of the model. He can use it more effectively if he knows how to break it.

It is easy to mislead the user by letting them work at the detailed level, and then returning to the summary level. The user can be led to believe that there is a great benefit to be gained from an ECO at the detailed level, when it actually offers very little benefit at the macro level. It is very difficult to incorporate this anomaly in a working layered costing procedure.

What is the replacement time period for new technologies relative to more conventional technologies? This is more important than the actual cost of the new technology (which is very subjective).

DISCUSSION OF TARGET SETTING REQUIREMENTS

- Morse: Detailed costing only has credibility when the numbers are a designer's own numbers. He cannot afford to trust someone else's number implicitly.
- You cannot impose decisions on the designer. The designer ultimately has the choice of how to comply with the standard.
- Gair: The effectiveness of the project will be to use cost data for technologies which is available in databases for existing buildings.
- Morse: There needs to be an open structure for this tool, because it will get used in ways that any of us in this room cannot perceive of right now.
- Briggs: I am concerned about skepticism about the credibility of macro level costs.
- McFall: There is never a chance to test the macro costs. This is the origin/cause of the concern. The detailed data which underlies the macro needs to be there. It may rarely get looked at, but the designers will insist on knowing what the source of that number is. They will feel much better just knowing how the macro data was arrived at.

3.2 Consultant Comments

The consultants prepared their comments in writing during the workshop. As with the energy simulation workshop comments, the building costing comments are reproduced essentially as written, to preserve the authors' original intent.

Comments by Bob Gair

General Comments

- Identify a market within the scope of an energy cost target to work with as pilot program.
- Keep the level of system/data detail high enough to compete with the user resistance.
- Identify and sell the concept of energy cost as a benefit to ensure acceptance.
- The current market-mood of acceptance is in the owner--e.g., IBM, Eastman Kodak, Northrop, GE.
- Plan the overall building cost strategy from the conceptual and systems stage with detail.

- Let the market aid in dictating the levels of detail required for building cost and operation and maintenance.
- The database should be from a proven database management firm.

There is a push within the owner (Ind 1000) sector to prepare more detailed and consistent estimates with an identifiable source of cost reference. There is a need for cost saving and cost control.

Design analysis needs must consider who the end users are and reference them to current, acceptable tools in the market today.

Don't necessarily reinvent the wheel (software systems), particularly in the first phase of a deliverable product.

I strongly question the separation of the "magic 100" modules in a computer model and a quick-fix template to key in building components for more detailed data. I am not convinced of the practicality and/or usage of such a vehicle. It seems to me that you would phase your system design so that it is fluid, having systems detailed with a database linkage throughout. On the other hand, the cost built on an exact system may be prohibitive.

The level of detail of building types appears to be correct, i.e., foot print, thermal zone, lighting spaces for conceptual phase. From this level we should proceed to accomplish the monumental task of completing cost database linkage throughout all estimating levels. Clearly, trade-off choices must be made.

Recommendations

- Target the industrial-type market; acceptance to cost benefit/savings would be stronger. The mood to improve estimating methodologies within the market is evident.
- This market would give a better appreciation of the product; a potential of acceptance; and would give level of building cost detail that would ultimately be required.
- This market should also be more sensitive to all system applications, designs, levels of cost detail, and levels of component detail on operation and maintenance.
- The system design must be coordinated with vendors to provide the best linkage and redundancy of activities.
- Don't lose sight of the end user's need with respect to the relationship between energy cost and building type.

Comments by Bob Morse

Potential Targets methodology users are concerned about how and when they look at capital budget and energy budget.

Be careful to stay within the scope of expressing budgetary differentials due to energy considerations separate from life-cycle analysis. Each user will have separate life-cycle cost analysis parameters, projections, and techniques.

Structure the design analysis for developing the budgetary targeting database so users are implicitly familiar with the assumptions, approaches, and sensitivities of your program/module. Almost all will want to customize it with their data and their perceptions.

Don't try to make your module stretch to link with everyone's/anyone's database. Instead, use a standard WBS that fits your functionality (most likely UNIFORMAT) and develop a standard format (preferably ASCII) for data input. Users can then enter their own data as they want. If Means, Dodge, et al. see value in the marketplace for supporting the model, they will develop a data download for your template. Remember, the federal agencies will want to use their own inhouse databases (e.g., CACES for the Army).

In developing your 100 technologies models, remember to develop them for a clear, single-function structure and not for a mixed-use building. Also, use real federal projects along with their own data--a case study approach. This accomplishes two things. First, a reality check is made to decide which technologies have the greatest potential for real dollar savings. If there is no significant savings, there will be no reason to publish (program) them. Second, by publishing the model with actual, verifiable buildings, you are not placing expectations beyond deliverability. This will encourage the users to work the model to develop a database for their types of buildings while avoiding the complexities of a multi-use building that users will find difficult to relate to the KISS principle. Avoid presenting the model as a final analysis tool. Since it is used for budget targeting and choosing design development alternatives, it can't be accurate enough to represent final analyses. If you build it to be capable of final analyses, it will be too complex and cumbersome to develop or maintain data for.

What users will seek here should be of primary concern. Approximations from design analyses details are both appropriate and acceptable to the nearest percent. If a user gives a budget building cost output (preferably broken down by your major WBS sections), the energy increments are relative to it. For example, doing alternate A adds 5% to a mechanical central plant and 2% to distribution, but reduces kWh demand by B or 8%. Thus, at a kWh rate of C it pays back in D months before escalation, cost of money, and price variability. A broad assessment of the changes in HVAC O&M and replacement time periods and dollars per year per SF increments should be given. The module should provide data to be used in a subsequent life-cycle analysis model and nothing more. Also, be sure that the target setting mode runs from the same algorithms as the design analysis so there's continuity and consistency.

Besides good documentation of the modeling approach, discuss how it can be broken or misused. Often someone understands it better by understanding why it doesn't work in a certain situation.

Make sure each analysis is sensitive to scale. For example, the effects of a shading system reach irrelevancy at some point. Conversely, energy savings or premiums often work on plateaus of use or under ceilings of energy efficiency. The energy saving/cost of a particular technology can only be so much per unit (i.e., machine set) while the area/space per unit can vary widely by application and/or climatic region.

Comments by Jim McFall

Energy is currently a commodity in the world market. Thus, it is subject to the wide cost range that goes with various fuels. Prior efforts to conserve energy were severe in some cases and caused problems. Current efforts will be received with more criticism.

There are several users' groups, each with a different agenda. Most are separated by how they view cost and value, e.g., capitalization cost and associated financing; operating cost; tax impact, depreciation expense; and time.

The decision making process of a project isn't always made by the end user.

Past estimating models used by our firm for a conceptual model of alternative systems utilizes the following methods:

- the recognition that cost/unit varies with size (i.e., a 2000-cfm fan doesn't cost twice as much as a 1000-cfm fan)
- the recognition of the law of numbers--There is a need for a number of line items. Errors are offsetting (math expression for a history of values with probable error).

A + or - a

B + or - b

C + or - c

D + or - d

i.e., $(A + B + C + D) (+ \text{ or } -) \text{ sq. rt. } (a^2 + b^2 + c^2 + d^2)$

i.e., square roots of sum of squares.

- group fix cost with method to handle variable example (calculation based on 1986). Future year numbers are adjusted by an index.

Should use existing data sources, i.e., Dodge or Means.

This tool will deal with issues that are at the highest levels of most firms that participate since they are concept- and decision-based. It may be difficult to get all of the information shared because of competing time and money.

This tool will be used by the conversant user. Thus, they will want to have access to information, tools, and methods currently not available to them.

Industry is an application technology field. Innovation and development efforts are slowly accepted, not because of lack of desire, but because so many different parties are involved: manufacturers, distributors, sales, engineers, contractors, services, users, and operators.

Innovative systems for consideration might include

- direct and indirect evaporative cooling
- liquid over-feed refrigerator systems
- screw compressors
- vacuum freezing and eutectic freezing
- ice storage, night cooling
- central heat pumps
- cogeneration.

Current problems with IAQ will lead to more outside air, more treatment, filtrations, humidification, and dehumidification; thus, the need for psychrometrics calculations.

Statistical methodology provides more confidence between systems modeled than between model and actual experience, data collection, data manipulation, data interpretation, utilization of interpretation, recognition of consequences, and anomaly.

Regarding the building cost module of the Target model, look at presenting several of the more frequently rejected or overlooked options as the examples used in the module, i.e., air-side economizer. Break out groupings to lighting, people, ventilation, conduction, solar, air conditioning, heating, and domestic hot water.

In setting targets, the following need to be considered:

- Building type (use)
- Lights/ft²
- HP/ft²
- CFM/ft²
- Ton/ft²
- BHP/ft²
- OSA/ft²
- People/ft²
- Occupancy (hours/day, days/week, days/year)
- Degree day cooling
- Degree day heating
- Indoor design
- Outdoor design

Consider using the methodology by Spielvogel.

Comments by Al Paxton

Assumptions

The project will yield a product (stand-alone), not a template. The product will be PC-based. The optimum is two 720-kbyte 3-1/2-in. diskettes.

The product will contain data on total building costs. The construction system in the product will be specified by the user if the defaults are not acceptable. For example, a membrane roof cover may be overridden for a steel deck with concrete topping and foamed polyurethane.

The user, in order to have acceptable conceptual total building costs, will specify such things as ZIP code (which will assume a climate and building code adjustment), supported by national database, occupancy or use (e.g., office, warehouse), class of construction, quality level by building and energy package, and number of stories, story height, perimeter of shape, and elevators and/or sprinklers.

These entries will be data-entry-oriented (no icons) and will all appear on one screen.

Occupancies should cover 180 to 200 building uses. Class of construction should be either ABCDS or ISO-oriented with five or six classes. Quality adjustments should be 4 to 5.

Now you have a conceptual building estimate, ready to be modified by varying energy-related construction systems or assemblies, not components. Components 1) do not belong in conceptual

estimating, 2) take up too much storage space, and 3) are not worth the incremental benefit of knowing the Btu dollar savings of a 60-watt light bulb over a 75-watt light bulb.

You will need 1000 models (200 x 5), each with a low- and a high-cost point, using a curve-fitting algorithm to fit two midpoints. Now you have cost bases on which to adjust for the number of floors/stories, the total floor area, the shape of building, and the elevators or sprinklers.

In each model you'll need to have defined target energy-related building specs.

I've tried to bring you from a top view down to a target assembly view. Now let's address areas of concern as we go from the details back up to the top view.

Concerns

Whether you're going to provide data or not, you'll have to assemble a task force to "spec out" the target energy-related assemblies or systems. This will then be the "material take-off" used by the data supplier to allocate geographically localized labor and material costs.

- This task force should be made up of conceptual estimators rather than detailed estimators. What you're trying to define are envelope packages. Detail-oriented people have a difficult time arriving at a group consensus.
- One alternative is to put this target package modeling out for bid. My gut tells me 1) you wouldn't get any takers from nationally recognized organizations and 2) no one-man shop can do it.
- Can your project manage ten individuals in remote locations to build these packages?

Now, how to modify these packages. The same task force has to design substitute input packages.

- I'm against letting the targeted audience for the targeted purpose specify individual construction components for detailed estimating. Why? The user will be bogged down in component entry, look-up, and too many screens/windows.
- How much time (or dollars) is any architect/engineer willing to spend in front of a PC on a conceptual estimate?

Individual detailed components do not lend themselves to square-foot-cost conceptual estimating.

The user should know exactly what is in a package. However, if the duct run is 100 lf in the package and the user wants 200 lf (or, if he wants more money), then the user adjusts the rank or quality level of the package.

- Rank is a judgment call based on material quality, job efficiency, etc. It's a way of specifying a point in a dollar range of package prices.

Once the user has "signed off" on all packages, the conceptual estimate is finalized. When the file is saved, only the material take-off is saved, not the data. That way when the file is recalled or reloaded, changing the date stamp, the zip code, or any building characteristics will cause this modified module to be recalculated. When the data file is revised, it has no effect on the save file; when the save file is loaded, it is recalculated according to the new data.

- What about the user overriding prices? Are they saved in the file? Are they protected from writeover with data update? Or are prices only changed by varying quality ranks?

General Comments

The DOE team hasn't settled on who the ultimate user is. Without a definition of the user, all brainstorming is circular.

The users are all architects. If a heating and mechanical engineer with ten years of experience can use it with benefit, then great, but the mass audience is the generalist architect.

Not everyone has an IBM PS/2 with an 80-megabyte hard disk. Since it is conceptual estimating, save disk space by using statistical algorithms. While the algorithms may sacrifice detail estimating, accuracy will buy product space for a national database, building occupancies, and quality adjustments.

A product can't be both macro and micro in its estimating philosophy and accuracy.

The product needs a mission statement, three objectives, and five goals/milestones per objective.

No vendor that I'm aware of has the "cutting edge" ME components with sufficient detail to satisfy your target concept. Nor does any vendor have the desired level of ME expertise. You need to contract it out or do it yourself.

There should be annual or semi-annual updates. Wages change in 6-month intervals.

You need to view more products. The world is not ICONS. For an experienced user, the pictures and pull-downs can get in the way of the input. An uncluttered screen is more eye-pleasing.

DOE team needs to diagram an A/E or ME estimating workflow, then develop a field form or estimating worksheet. Then they need to develop the screens to support the way an estimate is built.

Comments by Ken Sigel

If the program is going to generate an answer which is reliable, the building construction costs, of course, are going to have to be accurately (reasonably) predicted. This is going to have to occur before designs are suggested, or even begun in many instances. The single biggest factor in getting user acceptance is going to be the reliability of the cost prediction.

It is quite reasonable to expect to get reliable design phase cost predictions from limited design development. The reliability of those predictions is going to be proportional, in a large part, to the structure or format of the estimate itself. The format of the estimate has to be in a systems format; where those systems costs are obtained is really a secondary issue. In the target setting mode, they may be little more than historically generated proratings, and, like it or not, their quality will be directly proportional to the abilities of the compiler.

I guess this is all pointing to a "template" approach to the cost estimating, perhaps one which could readily accept information from commercially available databases. The key to the viability of the template is, again, going to be its structure. There are several qualities that are essential to an effective estimate structure. First and foremost, it must be built of the components in which architects design (structure, exterior closure, etc., not miscellaneous metal, concrete, and reinforcing steel). Second, it should not make

unrealistic demands on the level of design development; i.e., it should not have an unrealistic appetite for detailed information. Third, its structure should reveal the level of detail/accuracy upon which the estimate is based. Often the tendency is to imply that much more is known about a given design solution than actually is, and fancy programs often aid and abet this tendency (e.g., taking \$45/SF for a curtain wall and breaking it down so far as to show LF of sealant).

All of this applies to each phase of the design. Let me add, though, that the structure of the estimate should respond to the probable real-life flow of information into the design. Ask too many questions and you'll get no answers, resulting in no one using the program.

I think that your group should contact people who make estimates for a living; that is, people who make design phase estimates. Look at their work, visit them, see actual estimates of actual projects, compare them with the data (drawings, etc.) available at estimate time. The project needs an education in how estimates are made and used. People in the general data collection publishing business are not in the estimating business. Once that has happened, I think a group could be assembled to develop the estimate portion in an orderly way, and again later for big databases. My suggestion is to look to contractors, mainly large ones, and professional estimators rather than designers and publishers to develop this structure.

And as for a target market for this estimate package, I feel that it is going to be the informed user. There are many design professionals who are currently making estimates similar to the ones I am envisioning.

I think you want to start small (simple) and get, say, a macro-level format working well before you get too fancy. As for dealing with the energy-saving technology/systems, it should be quite easy to develop estimates for each, and my guess is that each energy saver will, at each phase, have an appropriate level of detail. Again, my view is that the database should be thought of as a secondary issue. Nevertheless, the format should be receptive to and compatible with existing databases.

Issues of scale/quality/proprietary items are usually dealt with in an estimating environment as it impacts cost. Any estimating package that you develop is going to have to leave those issues to the design professional. These issues are a major weakness in the existing commercial databases and correcting the weakness is probably not feasible.

Credibility is going to be hard to achieve. To a large degree, the extent to which the estimating uses a template and requires user input and/or review will be directly proportional to the degree of acceptability by the designers.

Updating and/or adjusting databases for time and place is always tricky. The degree to which the canned databases "plug-in" should help the life of the basic program. Having the system flexibility should be very visible to the user, which will help user confidence and acceptance.

I have heard a lot of talk, pro and con, about making whole-building estimates versus energy-saving systems estimates alone. It seems that it would be nice (and why not) if the user could choose to ignore the basic building cost if he wanted to. Maybe the user could choose whether or not to put in a "plug number" or a zero for the basic building cost.

My instincts tell me that as you become more detailed and advanced in design and, therefore, in the related estimates, it will be simpler to display/tinker with the estimates.

The system should be able to be coarsely updated with an accepted index, preferably several accepted indexes. It should also leave the frequency of updating to the user, enhancing his degree and sense of control over the quality of the project.

One potential pitfall is that of a broad brush, down and dirty estimate for each of the energy-saving systems. Many of these systems are sensitive to single/key elements, and often these variables slip through the cracks in a "quick" pass.

Summary

Educate the team about how WH estimates are made and used.

Develop structure of estimates that are

- appropriate to real design phases
- flexible (by usage, by overall factor, by scope)
- indications of appropriate detail level

Develop database as "add-on," not an integral.

Develop systems in realistic increments.

Remember systems format is critical.

Remember a system is only as good as the user (individual database).

Use estimates, structures, etc., designed by estimate professionals, and the building industry (credibility of "canned" systems is not good).

Distribution

No. of Copies

No. of Copies

Offsite

12 DOE/Office of Scientific and
Technical Information

5 M. L. Bailey
U.S. Department of Energy
1000 Independence Avenue SW
Forrestal Building, CE-131 5E-098
Washington, DC 20585

J. J. Boulton
U.S. Department of Energy
1000 Independence Avenue SW
Forrestal Building, CE-131 5E-098
Washington, DC 20585

D. Anderson
Burt Hill Kosar Rittelmann Associates
1056 Thomas Jefferson Street
Washington, DC 20007

C. S. Barnaby
BSG Software
760A Gilman Street
Berkeley, CA 94710

R. D. Busch
R. D. Busch & Associates
8209 Sprenger NE
Albuquerque, NM 87109

J. J. Deringer
The Deringer Group
1349 Addison Street
Berkeley, CA 94702

H. K. Diemer
David Mintz, Inc.
330 West 42nd Street
New York, NY 10036

J. A. Fireovid
The Fleming Group
55 Colvin Avenue
Albany, NY 12206

R. Gair
R. S. Means
P.O. Box 800
Kingston, MA 02364

C. Gardner
Puget Energy Services, Inc.
Suite E175
1750 112th Avenue
Bellevue, WA 98004

J. Hall
Carrier Corporation
Suite 101
1900 Embarcadero
Oakland, CA 94606

J. D. Hall
ICF Incorporated
Suite 700
409 12th Street SW
Washington, DC 20024

G. A. Hauser
Gregg Hauser Consulting
P.O. Box 20657
Oakland, CA 94620-0657

D. Hittle
Solar Energy Applications Laboratory
Colorado State University
Fort Collins, CO 80521

J. Holton
Burt Hill Kosar Rittelmann Associates
1056 Thomas Jefferson Street
Washington, DC 20007

**No. of
Copies**

B. K. Johnson
State of New Mexico
Energy, Minerals, and Natural Resources
Department
Energy Conservation and Management
Division
525 Camino de los Marquez
Santa Fe, NM 87501

J. W. Jones
University of Texas at Austin
Engineering Teaching Center
26th & San Jacinto
Austin, TX 78712

J. E. Kaufman
Illuminating Engineering Society
of North America
Ninth Floor
345 East 47th Street
New York, NY 10017

J. McFall
McFall, Konkell, Kimball
2160 South Clearmont
Denver, CO 80222

H. N. McKay
Hayden McKay Lighting Design
Ninth Floor
31 West 21st Street
New York, NY 10010

R. Morse
CRS Sistine
Suite 600
1177 West Loop South
Houston, TX 77027

A. Paxton
Marshall Swift
P.O. Box 26307
Los Angeles, CA 90026-0307

J. Pegues
Carrier Corporation
P.O. Box 4808
Syracuse, NY 13221

**No. of
Copies**

M. Schwedler
Trane Company
3600 Pammell Creek Road
La Crosse, WI 54601-7599

W. W. Seaton
American Society of Heating, Refrigerating,
and Air-Conditioning Engineers, Inc.
1791 Tullie Circle, NE
Atlanta, GA 30329

D. Seth
Public Works, Canada
Room C-537
Sir Charles Tupper Building
Ottawa, Ontario K1A 0M2
CANADA

K. G. Sigel
Wolf & Company
P.O. Box 275
Pleasantville, NY 10570

F. Winkelman
Lawrence Berkeley Laboratory
Building 90-3145
1 Cyclotron Road
Berkeley, CA 94720

Onsite

DOE Richland Operations Office

R. B. Goranson

18 Pacific Northwest Laboratory

P. K. Alley, K7-44
M. R. Brambley, K5-19 (5)
R. S. Briggs, K5-19
D. B. Crawley, K5-19
B. M. Johnson, K5-12
L. D. Kannberg, K5-12
T. J. Secrest, K5-12
G. L. Work, K2-51
Publishing Coordination
Technical Report Files (5)